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ADVANCED MATERIALS
FOR BIO-RELATED APPLICATIONS
19-23 May 2024 Wroclaw, Poland

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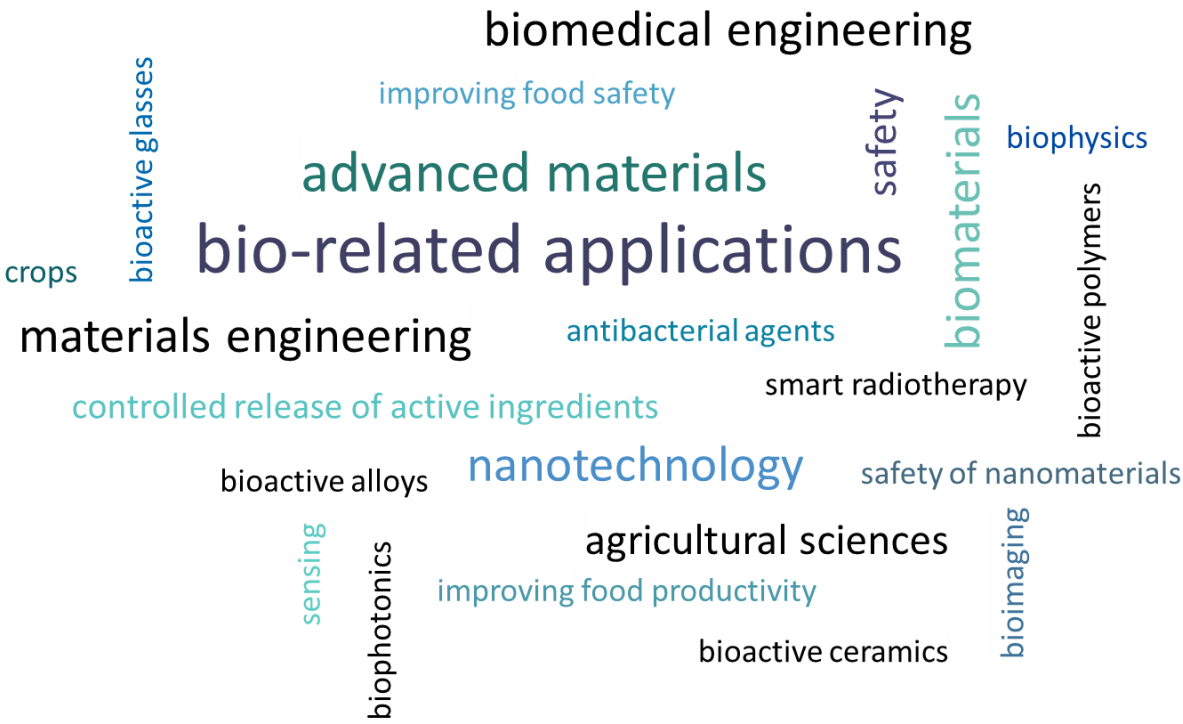
PURPOSE OF THE CONFERENCE

The aim and mission of the AMBRA conference is to present the current state of progress in R&D in the field of materials engineering as well as biomedical and agricultural sciences and to create a forum between the participants to discuss achievements and cooperation in the interdisciplinary studies on the subject of the meeting. Discussions will be conducted on the matters in the area of nanotechnology, advanced biomaterials, orthopedics, cardiac surgery, tissue engineering, facial-jaw engineering, pharmacy, biomechanics, agriculture, medical equipment, and others.

Of the main interest are issues related to biomaterials and nanomaterials for biological, medical, and agricultural applications.

CONFERENCE TOPICS

The conference topics include but are not limited to:



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PLENARY TALK
2nd International Conference on Advanced Materials for Bio-Related Applications

Natural polymers who can talk to microbes: can this conversation make us carbon neutral?

Markus ANTONIETTI

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"Polymer chemistry" can create some of the beauties of civilization, but also can tackle the serious downsides of non-closed global element cycles. In a fictive world of circularity and sustainability, it will become difficult for the current "fossil" business schemes, and biomass as a source of monomers and polymers is an obvious alternative. However, biomass usually comes with water and chemical functionality, making our current catalytic toolbox rather poor. Hydrothermal reforming (HTR) and hydrothermal carbonization (HTC) are chemical processes to turn carbohydrates (including crude forestry side products, but waste biomass in general) into diverse products. All these processes occur also naturally, the products mostly well known, but engineering can be highly accelerated within "noble steel". I will introduce these now classical processes, but focus on "hydrothermal humification", where the polymer product turned out to be extremely useful for agriculture and soil remediation. Contrary to our primary expectations, these polymers do not only act by their physical chemistry, but opened a previously not accessible biological "universe". Two billion hectares of arable land are actually affected by moderate to severe soil degradation and actually need two billion tons of humic substances, which in return then probably sequester up to 350 billion tons of CO2 through living matter system engineering of soil microbiology. That is no less than the equivalent to the amount emitted by humanity in the last ten years.

If time allows, I will dare a discourse on creativity and scholastic restrictions. The question is why it is so difficult to see the sometimes most nearby solutions and how education also outside the core disciplines is expanding our analytical capabilities.

Tuning the formation of reactive oxygen species mediated by exogenous photosensitizers for efficient photodynamic therapy of cancer and bacterial infections

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Interaction of partially reduced oxygen products and singlet excited molecular oxygen (singlet oxygen), commonly termed reactive oxygen species (ROS), with key cellular constituents, could lead to disfunction of the cells and ultimately their death. Even though such processes are believed to be responsible for ageing and certain diseases, controlled formation of ROS in pathological tissues might be exploited as alternative treatment for cancer and bacterial infections. This treatment, called photodynamic therapy (PDT) and antibacterial photodynamic inactivation (APDI), is based on localized generation of ROS using appropriate photosensitizing dyes, molecular oxygen and active light. Although singlet oxygen is generally viewed as a key species responsible for photodynamic oxidative damage, its photogeneration requires relatively high oxygenation of the treated tissue. At low concentration of oxygen, Type I photochemistry prevails with the dominant role of free radicals. This paper will discuss the mechanisms of significant potentiation of photodynamic inactivation of both gram-positive and gram-negative bacteria by a wide range of different inorganic salts, which contributed to the formation of different oxidizing radicals. The preferential Type I or Type II photochemistry in photodynamic killing of in vitro cancer cells using Pd-substituted bacteriochlorophyll derivatives or functionalized fullerenes and surface-modified TiO2 nanoparticles will be also briefly reviewed. The reviewed collaborative studies were caried out employing standard cell and molecular biology techniques and selected physicochemical techniques such as laser flash photolysis, singlet oxygen phosphorescence, EPR-spin trapping and EPR-oximetry, and detection of lipid hydroperoxides by HPLC-EC(Hg) using cholesterol as a reporter molecule. Although the exact role of free radicals and singlet oxygen in cancer and antibacterial PDT remains difficult to be unambiguously determined, tunning the specific formation of ROS may be utilized to optimize the efficiency of the treatment.

Acknowledgement

The reviewed studies were done in collaboration with the Professor Michael R. Hamblin group of the Department of Dermatology, Harvard Medical School, Boston, MA, USA and the Professor Avigdor Scherz group of the Department of Plant Sciences, the Weizmann Institute of Science, Rehovot, Israel.

Funding

The studies were supported by grants from the National Institutes of Health (USA), STEBA-BIOTECH (France) and National Science Centre (Poland).

Metallo-elastomers for biomedical applications

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biomaterials, elastomer, metal ions, catalysis

Elastomers are network polymers typically crosslinked by strong covalent bonds and are widely present in nature and in manufactured goods. Weak bonds can also crosslink elastomers, but the product usually exhibits more plastic deformation. Using coordination bonds to crosslink elastomers is a virgin territory. Here I report our exploration in chelation as a mechanism to produce biodegradable elastomers. Chelation offers a unique advantage in that one ligand binds multiple metal ions yielding bonds of different strengths. Therefore, one polymeric ligand coordinated with different metal ions produces polymers with vastly different characteristics. Those with strong chelation bonds match the low hysteresis of covalently crosslinked elastomers. Furthermore, chelation offers the opportunity to incorporate bioactive metal ions. I will discuss our work with copper which is pro-angiogenic and catalytically decomposes reactive oxygen species. Acellular vascular grafts made of the elastomer transform into autologous vascular conduits in vivo with robust expression of elastin. There are many elastic tissues in the human body. These biodegradable elastomers could enable new possibilities in treating disorders in soft tissues.

Funding

This research is supported by NIH grant #1R01EB032450 and grant #R01HL159427.

Oligonucleotide Switches for Optical Biosensing

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Oligonucleotide optical switches can be defined as specifically designed short nucleic acid molecules capable of turning on or modifying their light emission on molecular interaction with well-defined molecular targets. The optical principle of the switch can be based on fluorescence and in particular on Förster Resonance Energy Transfer (FRET) and on Surface-enhanced Raman scattering (SERS) [1].

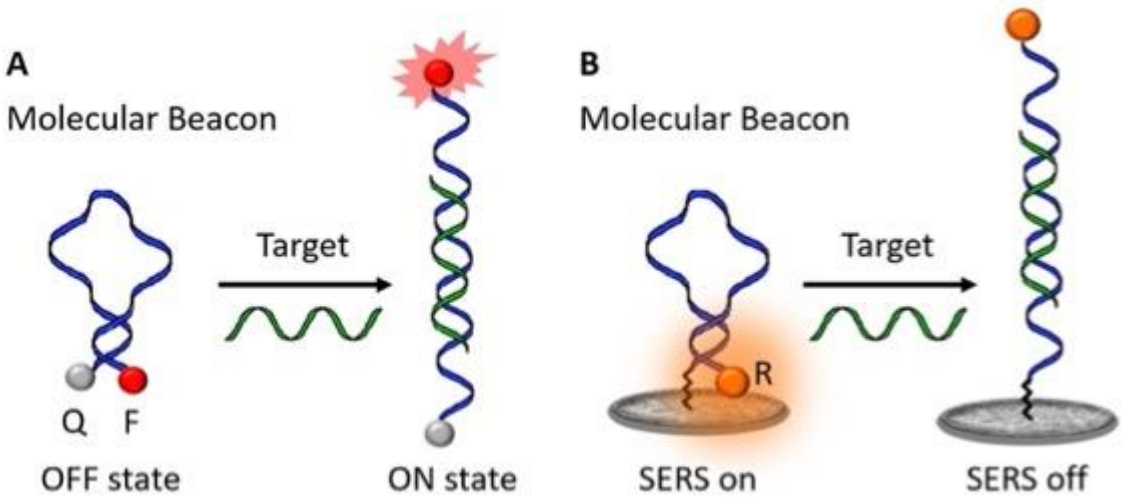

Figure 1. Oligonucleotide switches: molecular beacon based on A) FRET and B) SERS

DNA is a powerful molecule: with DNA fragments, researchers in the biosensing field not only give specificity to their analytical system, but they can build extraordinary tools with which life inside cells can be spied on and which can be used at the same time for sensing and for therapeutics. In this context, oligonucleotide optical switches, DNA molecules capable of modifying their light emission upon interaction with well-defined targets, are among the most promising optical nanosensors proposed in recent years [2].

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Funding

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Towards full control of bio-molecules with electromagnetic radiation

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Non-ionizing electromagnetic radiation can in-principle fully control bio-molecules, leading to potential future safe therapies. However, this requires several conditions to be satisfied. First, the radiation must be very selective in targeting the specific biomolecules in spite of the nonlinearities of the interactions. Second, the range of used frequencies of the EM radiation must lie in the transparency windows of the biological system. Third, one must overcome the evolutionary spectral similarity problem, which makes spectral response very similar to a variety of unrelated bio species.

In an earlier study [1], we have demonstrated that the spectral resolution of the bio-molecule interaction with the long wavelength EM can remain very high, even at the bio-molecule dissociation threshold. Even though our simulations considered a specific Peyrard-Bishop-Dauxois model of a DNA molecule, our calculations based on the fold catastrophe universality class of Thom's catastrophe theory shows, that the results are valid for a variety of bio species. This opens-up the possibility of resolving the first, spectral selectivity problem.

In this work we study the possibility of addressing the remaining two problems with application of piezoelectric nanoparticles. These are distributed throughout the bio system and are activated by ultrasound. Then, they become localized point-dipole like electromagnetic wave sources which dramatically enhances both the spectral and the spatial resolutions. Since these nanoparticles can be bio-functionalized to attach/enter a desired target bio-specie, this could help with the third similarity problem. Finally, since the initial excitation of the piezo-nanoparticles is with ultrasound, the second problem is also resolved, since ultrasound waves penetrate well biosystems in a wide frequency range. We have begun a strong simulation effort in this study, and preliminary results will be shown.

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Glycobiology for cell targeting in hypoxia-dependent pathologic microenvironment

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Any organ needs oxygen presence and supply to survive and function.

The 2019 Nobel Prize awarded to Gregg Semenza, Michael Kaelin and Sir Peter Ratcliffe [1-4] crowns research dedicated to identifying and deciphering the biological mechanisms that are both affected by and regulated by O_2 supply, with the biological consequences of this regulation [5]. Diseases progression is enabled by the establishment of hypoxia in the cell microenvironment. Hypoxia is the partial oxygen pressure below the physiological value i.e. physioxia which depends on the needs to maintain the homeostasis in an organ or tissue [6]. This concept is of fundamental importance, as physioxia values range from 11% in the pulmonary alveoli to 1% in the skin.

When a mechanical or physiological damage occurs, gas exchange is affected compromising O_2 supply, triggering the angiogenic "switch" by endothelial stress responsible for environmental conditioning and reorganization that is permissive for the continuation of the pathology.

A great many pathologies depend on proangiogenic signal and endothelial damage to progress. Those include cancer, diabetes, endometriosis, cardiovascular disease, pulmonary insufficiency and nerve degeneration (Alzheimer's disease, Parkinson's disease, ALD, etc.).

Cancer is the most widely documented pathology that progresses and becomes independent of immune control as soon as hypoxia is established. As O_2 diffusion is limited to 100 µm, hypoxic signals appear very early during tumour growth. To compensate oxygen deficit angiogenesis is switched on but exacerbated proangiogenic factors by tumour cells destroy the equilibrium in favour of hyper-formation of vessels by budding, and various other mechanisms, including vascular mimicry by hypoxic tumour cells. New formed vessels in such anarchic angiogenesis are not functional, not allowing any blood flow and maintain the environment hypoxic, thus forcing in situ and/or recruited cells, as immune cells to evolve.

Such changes deeply affect the understanding of **targeting** since tumour and microenvironment cells do express strongly modified receptors in terms of quantity and specificity in hypoxia.

Melanoma has been widely documented. When the tumour gets hypoxic, cells recruited to fight the tumour are either qualitatively distinct or undergo phenotypic and functional

changes influenced by the hypoxic microenvironment. As such, macrophages (M1 type, active anti-tumour cells) acquire, under hypoxia, the M2 phenotype (pro-tumour and pro-angiogenic cells). Highly significant is the hypoxia-induced expression of immune control molecules (PD1/PD-L1, CTLA4, SigLECs, CD47....) [7-9], largely responsible for the failure of treatment strategies because they destroy the cytotoxic immunocompetent cells by blocking their access. Hypoxia also regulates tumour suppressor genes, controlling angiogenesis, as PTEN, which orchestrates vessel formation [10-14]. In addition, hypoxia regulates the balance between forms that enable the activation of major tumour suppressors such as p53 [15].

Hypoxia-dependent cellular interactions are not only vicinal but also paracrine by increased formation of exosomes, whose microRNA and protein composition is highly significant [16,17] and plays a key role in the formation of pre-metastatic niches [14].

Receptors based targeting strategies by tumor-toxic nanoparticles are illustrated in the melanoma for its ability to express sugar binding receptors. Their specific expression, modulation as well as segregation into vesicles are all hypoxia modulated processes. Glycosylated macromolecules tools help sugar-specific receptors identification and shows their potential use in treatment strategies.

In conclusion, knowledge of the role of hypoxia in the development of hypoxia-dependent pathologies, and in particular in the skin, should make it possible to rectify the interpretation of trial results in which this parameter is not considered, and open the way to the development of new strategies for therapeutic repair.

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Funding

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Single Nanocrystal Arrays for BioApplications

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Nanotechnology is about using single nanoscale objects in devices and applications. Of particular interest is single molecule sensing and tracking, which are important for disease diagnosis. For this purpose it would be useful to create patterned arrays of nanocrystals which can act as spectroscopic probes. Yet there are still few ways to reliably manipulate and position single nanocrystals with nanometre spatial resolution. In this talk, I will discuss the positioning of single nanocrystals into arrays using electrophoresis [1-3]. The method is general and can be applied to any colloid particle with well-defined surface charge and morphology. As a proof-of-principle we show that it can be applied to gold spheres and rods, magnetic nanocrystals and quantum dots.

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Funding

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Advanced materials for photocatalytic carbon dioxide reduction and ammonia production

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photocatalysis, carbon dioxide reduction, water splitting, ammonia production

Among the most important megatrends for the life on Earth nowadays are climate changes, clean energy and sustainable environment. To prevent dramatic climate changes, the anthropogenic emissions of greenhouse gases have to be limited. Carbon dioxide is one of the greenhouse gases, responsible for climate changes. Its global emissions in 2022 reached 36.6 Gt. Despite many successful CCS (carbon capture and storage) technologies, CCU (carbon capture and utilization) processes should be developed, enabling a transformation of CO_2 into useful products, as carbon monoxide, methanol, methane or other hydrocarbons.

Our research in the field is focused on the application of photocatalysis to CO_2 reduction, carried out on microporous carbon spheres decorated with semiconductor oxides (mainly TiO2 and ZnO). The role of the oxide is to enhance the photocatalytic reduction, while that of carbon spheres is to enhance the CO_2 adsorption and inhibit charge recombination. The modification with semiconductor oxides was performed in »one pot« synthesis or after the synthesis of carbon spheres, through impregnation. The photocatalytic tests were performed using a gas-phase or liquid-phase photocatalytic reactor with the bed in the form of a UV transparent glass fiber cloth coated with a photocatalyst. The photocatalytic properties of the composites containing titania or zinc oxide were compared. Hydrogen (product of the CO_2 mediated water splitting), carbon monoxide, and methane were produced in the photoreduction process [1]. It was found that TiO_2/CS and ZnO/CS composites showed similar activity in carbon dioxide reduction process. However, the higher addition of carbon spheres was more beneficial for the zinc-containing material.

We stated that a decrease of ZnO particle size 50 μm to 26 nm was favorable for the carbon dioxide photoreduction process efficiency. Additionally, good results were obtained also in the case when zinc oxide was totally dissolved in the liquid phase. Such a homogeneous method of carbon dioxide reduction and hydrogen production was declared under the Polish patent [2].

Photocatalysts based on commercial titania (P25) decorated with various metal compounds were investigated as well and platinum, ruthenium or copper addition were the most efficient.

Under specific conditions of the photocatalytic process, green ammonia formation [3] from nitrogen and hydrogen (generated in the photocatalytic process) can occur as well. The

bed in the reactor is located just above the water surface and the produced ammonia is easily absorbed in water and continuously separated from the gas phase, shifting the ammonia synthesis reaction equilibrium towards the product.

Combining carbon dioxide reduction and low-temperature nitrogen fixation to produce ammonia in one photocatalytic process would be an interesting challenge for the future.

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Funding

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Control of Macrophages with Piezoelectric Nanoparticles

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The advent of nanomaterials in biomedicine has spawned a range of new technological innovations and applications, from tissue engineering and drug delivery to tumor destruction. Adjusting chemiphysical properties of nanoparticles (NP), such as size, shape, and surface properties, is a major factor for optimization of targeting and cellular uptake, as well as intracellular trafficking. The role of bioelectricity in cell function, on the other hand, is understudied and less understood. Using piezoelectricity as the source of bioelectric modulation is one route to gaining important insight in this area. Piezo-electric (pz) materials convert mechanical energy into electrical, and vice versa, as a result of interaction between the mechanical and electrical states, generally in crystals with no inversion symmetry. Piezoelectric materials (discovered in 1880 by the Curie brothers) can be “activated” to produce a voltage by direct mechanical pressure, but also by ultrasound (US).

Macrophages are highly plastic cells with phenotypes influenced by both physiological and pathological conditions, such as tissue repair, infection, allergies, chronic inflammation, and cancer (i.e. via tumor-associated macrophages). They are highly phagocytic, ingesting cellular debris and foreign substances, and can vary from pro- to anti-inflammatory in function. Their activation status and persistence can be major determinants of the outcome of infection, inflammation, and cancer tumorigenesis. Methods to biochemically generate various macrophage subsets can be time-consuming and costly, or not applicable in vivo, and approaches to date have largely failed to generate therapeutically translatable effects. Cancer cells are similarly phagocytic, and can be targeted on that basis for preferential or specific uptake of targeted therapies. We are pursuing a bioelectric approach to macrophage and cancer cell modulation by creating a localized electric potential on endocytosed nanoparticles, which results in, among other effects, a current density that acts on voltage-sensitive ion channels. Thus, instead of drug targeting, we are applying piezoelectric nanoparticles (pzNP), activated by ultrasound (US) toward the selective and triggered control of macrophages and cancer cells.

We report here on the use of pzNPs ($BaTiO_3$, 100 nm diameter) activated by US in vitro to modulate macrophage polarization. In particular, pzNP@RAW264.7 cells + US stimulation controllably directs M0-stage undifferentiated monocytes into M1-stage pro-inflammatory macrophages, while unloaded cells are unaffected by the US. Moreover, high-level US stimulation of pzNP-loaded cells leads to cell death. We are investigating the mechanism(s) by which these bioelectric effects occur, as well as the extent to which similar effects result from pzNP@cells in vivo, where any putative therapy must function.

Differential analysis of volumetric changes in multiphase materials using microtomography

Anna NIKODEM

Microtomography is a tool that allows, in a non-invasive and non-destructive way, not only to obtain the spatial reconstruction of the samples under study, but also to quantify the parameters that determine the organization of the individual elements that make up this structure. Using the analysis based on image analysis algorithms, the application of this method provides the possibility of both qualitative and quantitative measurements. Measurements of structural parameters make it possible to determine parameter values in 2D histomorphometric analysis, as well as reconstructed objects in 3D analysis. During image reconstruction, a model is created that characterizes the radiological density of the material in different shades of gray. The study of composites and multiphase materials, due to the difference in radiological density of different phases, provides the possibility of volumetric evaluation of parameters describing each phase separately. Such parameters include, among others, particle size or volume fraction of composite phases. One of the research directions in which this analysis is an important element are studies related to the degradation of the material under the influence of external factors (time, environment or temperature). In this type of measurements it becomes very valuable to be able to compare the different stages of degradation, for example. Computerized microtomography, which allows to obtain reconstructions with a resolution up to um, based on differential analysis, is therefore an excellent tool for such measurements.

Microscopic Lasers as Biointegrated Sensors

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microlasers, nanolasers, optical sensing, intracellular lasers

Microscopic lasers combine the unique advantages of laser light with a small footprint and variable material choice, making them ideal light sources for biointegrated optical sensors. Consequently, they have found novel applications where e.g. their spectroscopic properties are used to identify large numbers of biological cells [1,2]. In addition, changes of the spectral positions of the laser modes are used for sensing various physical, chemical, and biological stimuli.

Here, we present different micro- and nanolaser devices for use as biointegrated sensors. These lasers have a typical size of 1-15 µm and are fabricated from either organic dyes doped into a chemically inert matrix or from inorganic semiconductors. They all have in common that they are non-toxic and provide a new way to extract biologically relevant information. As an example, the contractile properties of heart cells are characterized in detail on the level of individual cells as well as in in vivo experiments in zebrafish embryos [3]. By making the matrix of the microlasers mechanically flexible, biological forces can also be measured with high precision. Finally, we discuss the advantages of microlasers with respect to state-of-the-art microscopy techniques where we demonstrate that the high signal intensity and elastic nature of light scattering enable deep-tissue sensing at unprecedented depth and spatio-temporal resolution [3,4].

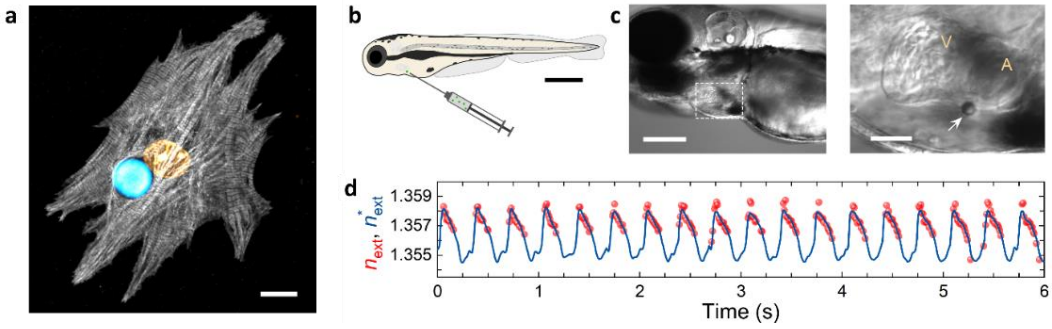

Figure 1, a. A confocal microscopy image of a neonatal cardiomyocyte with an intracellular microsphere laser (blue), stained sarcomeric protein cardiac troponin T (grey), and cell nucleus (yellow). Scale bar, 15 µm. b. in-vivo application of microlasers. c. (left) A brightfield microscopy image of the microlaser attached to the atrium of a zebrafish heart (3 dpf). Scale bar, 200 µm. (right) Magnified view of the zebrafish heart with the microlaser (arrow). Scale bar, 50 µm. d. Calculated contractility profiles recorded as changes in refractive index.

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Tailoring adsorbents and biocatalysts for sustainability challenges

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recycling of critical elements, water purification, POP, MOF, PFAS

Solid adsorbents constitute a promising alternative in answering to the request for improved sustainability of industrial processes today. One of the principal routes on this path is recycling of critical elements and purification of both wastewater and drinking water. Improved functionality requires tailoring of materials, using both suitable bearing matrices and the active ligand layers. Such constructions are most often hybrid materials with an inorganic or biopolymer matrix covered with grafted species specifically binding to target components.

One of the principal bottlenecks in recycling of critical elements is separation of Rare Earth Elements (REE) from Late Transition Metals (LTM), and especially, LTM present together in many electronic, magnetic and battery materials from each other. Selecting a proper ligand function permits to implement principally different binding mechanisms for REE and LTM, leading to enhanced selectivity both on adsorption and, especially, on desorption steps [1-2]. Ligands influencing oxidation states of LTM can offer a possibility to separate individual constituents of, for example, anodes of Li-ion batteries such as Co and Ni [3].

In the challenges for water purification two major problems have been identified. One of them is associated with accumulation of persistent organic pollutants (POP) such as pharmaceuticals. An efficient biocompatible and soft chemical route is oxidation of POP applying biocatalysts, most attractively, peroxidase enzymes. Maintaining the activity of the latter requires their protection. As a sustainable encapsulation matrix for enzyme biocatalysts can be used natural porous silicates such as LECA, PerliteTM, or silica gel produced from flying ash [4]. Another alternative for matrix material can be offered by purposefully constructed Metal-Organic Framework (MOF). Such materials have been produced via structural transformation and exfoliation of MOF formed by REE cations and benzene-tricarboxylic acid. The enzyme molecules were adsorbed on MOF nano sheets and built into microparticles by porous silica coatings [5].

Another kind of POP is Per- or Polyfluorinated Organic Substances (PFAS). Their removal and accumulation were carried out with complex polycationic functional layers [6].

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Biocompatible boron-based COF-1 towards antibacterial applications

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COF, antibacterial, biocompatibility, ROS generation

Covalent organic frameworks (COFs) are an emerging class of predesignable, crystalline polymers with highly ordered and tunable structures. COFs, which consist of purely organic units connected through powerful covalent bonds, exhibit good stability, small mass density, and permanent porosity. In combination with the unique properties of large surface area, adjustable pore size, and metal-free structure for good biocompatibility, COFs have immense application potential in the field of biomedicine [1]. Recent studies have shown that COFs may display excellent antibacterial activity, which can pave the way for innovative systems for treating bacterial infections [2].

The primary aim of this study was the synthesis, characterization, and determination of the antibacterial properties of boron-based COF-1. The material was obtained through a facile method of direct condensation of monomers under ultrasonic treatment and mild conditions. COF-1 was characterized structurally, spectroscopically, and texturally using different techniques such as PXRD, IR spectroscopy, TEM and SEM imaging, TG, and nitrogen sorption isotherm (77 K).

In order to demonstrate the bioapplication potential of COF-1, its biocompatibility with selected normal cells, such as human dermal fibroblasts (HDF) and mouse osteoblast precursor cells (MC3T3), was tested. Considering the photocatalytic potential of COF-1, due to the elemental composition (electron-deficient boron) and extended conjugation, its capacity to produce a variety of reactive oxygen species (ROS) under white light irradiation was checked. Finally, the antimicrobial effect of COF-1 against the representative bacterial strains (*Pseudomonas aeruginosa*, *Escherichia coli,* and *Staphylococcus aureus*) was conducted.

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Study of the influence of structural distortion and crystal lattice deformation on luminescent properties in mixed $Ca_{1-x}Sr_xF_2$ systems doped with lanthanide ions

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up-conversion, Yb-Er, fluorides, nanomaterials

In the last decades, many scientific publications have focused on upconverting nanoparticles (UCNPs) doped with lanthanide ions due to their applicable potential. The upconversion (UC) phenomenon is based on the absorption of low-energy photons (from the near-infrared region) to produce higher-energy anti-Stokes luminescence. [1].

This study examines how the structural disorders caused by replacing Ca^{2+} ions with Sr^{2+} ions in host matrice influence the spectroscopic properties of $Ca_{1-x}Sr_xF_2$ nanoparticles doped with lanthanide ions synthesized by a simple one-pot hydrothermal synthesis assisted with microwave. The physicochemical properties of $Ca_{1-x}Sr_xF_2$ nanomaterials were investigated by different methods, among others, XRD and spectroscopic measurements (emission spectra, luminescence decays, power dependence of the upconversion emission intensity on excitation power).

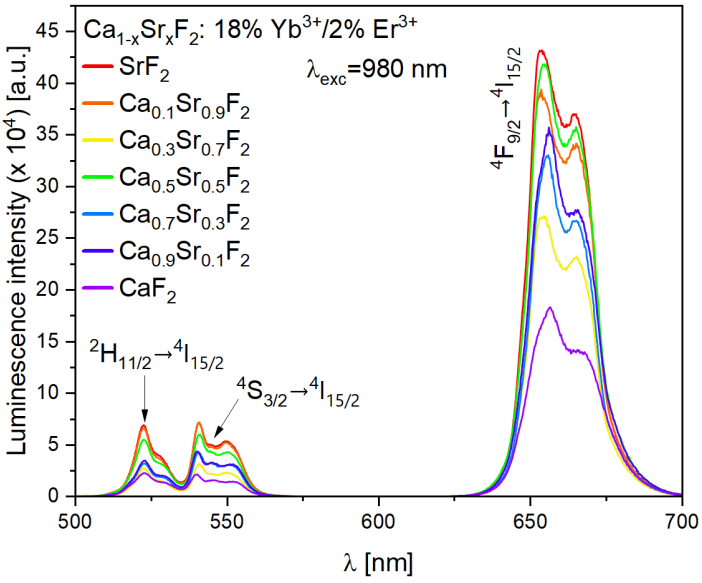

Figure 1. Emission spectrum of $Ca_{1-x}Sr_xF_2$ nanoparticles doped with 18% Yb^{3+} and 2% Er^{3+} ions.

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New functional composite for the treatment of bacterial bone infection based on hydroxyapatite and titanium metal–organic framework

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metal–organic framework, antibacterial activity, drug delivery, biocompatibility

Hydroxyapatite (HA) is widely used in medicine, including orthopedics (e.g. bone defects treatment or controlled drug release) and dentistry (as a component of implants) due to its bioactivity, biocompatibility, and good osteoconductive properties. A nanohydroxyapatite coating applied on a metal implant beneficially affects the change in the surface properties of the implant-tissue interface. However, HA does not lead to the inhibition of bacterial infections, which are still one of the most common causes of failures in bone regeneration [1].

As a solution to this problem, a new biocompatible composite with antibacterial properties, consisting of HA nanoparticles and titanium(IV)-based metal-organic framework with the acronym MIL-125(Ti)-NH_2 has been proposed. The solvothermally obtained material was characterized using various techniques, including PXRD, IR, TEM, TG, and low-temperature N_2 sorption. The biocompatibility of the composite was confirmed during *in vitro* tests on osteoblasts (U2-OS) and fibroblasts (L929) as model cell lines. The introduction of gentamicin, an antibiotic used in the treatment of bone bacterial infections, into the MIL-125(Ti)-NH_2@HA system increased the antibacterial activity of the material against *Staphylococcus aureus* and *Pseudomonas aeruginosa*. Additionally, the nanoindentation study showed an increase in the plastic work value of MIL-125(Ti)-NH_2@HA compared to pristine HA, suggesting that novel composite can be successfully used as a component in surface modifications of implants.

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Persistent nanoparticles – lipid bilayer interaction vibrational spectroscopy data

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persistent nanophosphors, Zeta potential, Sum frequency generation spectroscopy

The process of visualization of biological objects is directly related to the use of fluorescent probes. The efficiency of fluorescent probes is determined by the signal-to-noise ratio caused by autofluorescence and scattered light in the biological environment under constant external excitation in the ultraviolet or visible range. In addition, it is important to monitor the detection of post-treatment effects such as apoptosis, oncosis, etc. [1]. Another important point is to understand how nanoparticles (NPs) interact with cell membranes. Persistent emissions (PersL) NPs meet most of these requirements. One of the representative PersL NPs is ZnGa2O4:Cr3+ (ZGO:Cr) with emission in the red region, first reported by Bessière et al. [2]. In addition to the above-mentioned features, the process of interaction of NPs with cell membranes remains poorly understood.

In the current work, ZGO:Cr synthesized by the hydrothermal method [3] with the addition of oleic acid to obtain a surface charge were investigated. The Zeta potential for obtained ZGO:Cr was tested before further investigation. The vibrational non-linear optics response of the lipid bilayer after adding PersL NPs into the solution by sum frequency generation spectroscopy were detected to determine changes in the interfacial systems

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The influence of silica nanoparticles containing boron on growth of cucumber (*Cucumis sativus L.*)

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silica nanoparticles, boron, foliar fertilization, cucumber (*Cucumis sativus* L.)

Boron (B) is one of the essential micronutrients needed for proper growth and high productivity of plants. It performs important functions in the plant life cycle, and both deficiency and excess of B disrupt numerous metabolic and anatomical processes in plants. At the same time, the range of concentrations determining its deficiency or toxicity is relatively narrow [1]. In the soils of Poland and most regions of the world, boron deficiency is quite common. The role of B in plant nutrition is still the least understood of all the nutrients. Boron deficiency in crops is probably more widespread globally than deficiency of any other micronutrient. Probably, the most common and immediate reaction of plants to low B supply is the impairment in root growth and it is species specific [2,3]. Foliar application of nutrients, especially microelements, is a common practice, but the effects depends on many factors: time, humidity, type of solute (hydrophobic/hydrophilic), precipitation, penetration by stomata, accompanying ions [4]. Future research should focus on realistic risk assessment of nanoparticles in plants by measuring the rate of nanoparticles uptake, the size exclusion limit of the apoplast, and understanding the physiological characteristics of plants that promote uptake [5]. The use of many nanomaterials give rise to poisonous effects, which alters morphological, anatomical, and physiochemical changes within the plant system. Many other nanoparticles have been found to have growth regulating properties which brings significant increases in biomass and even improvements in nutritional quality. An issue requiring further research are mechanisms of transport of nanomaterials through plant cells and the entire plant [5-8].

Water suspensions of silica (SiO_2) nanoparticles (Ø 20 nm) with boric acid were used as a fertilizer providing plants with B. Applied boron-containing preparations resulted in a significant reduction in the weight of fresh and dry cucumber, both in shoots and roots, while regulating the water content compared to plants grown without B. The concentration of B in plant parts was significantly different. Silica nanoparticles with B applied to the leaf surface resulted in an increase in the B content in plants compared to plants grown without these nanoparticles and treated only with boric acid. Doubling the dose of boron in the preparation with silica resulted in the highest accumulation of B in all tested plant organs (Figure 1).

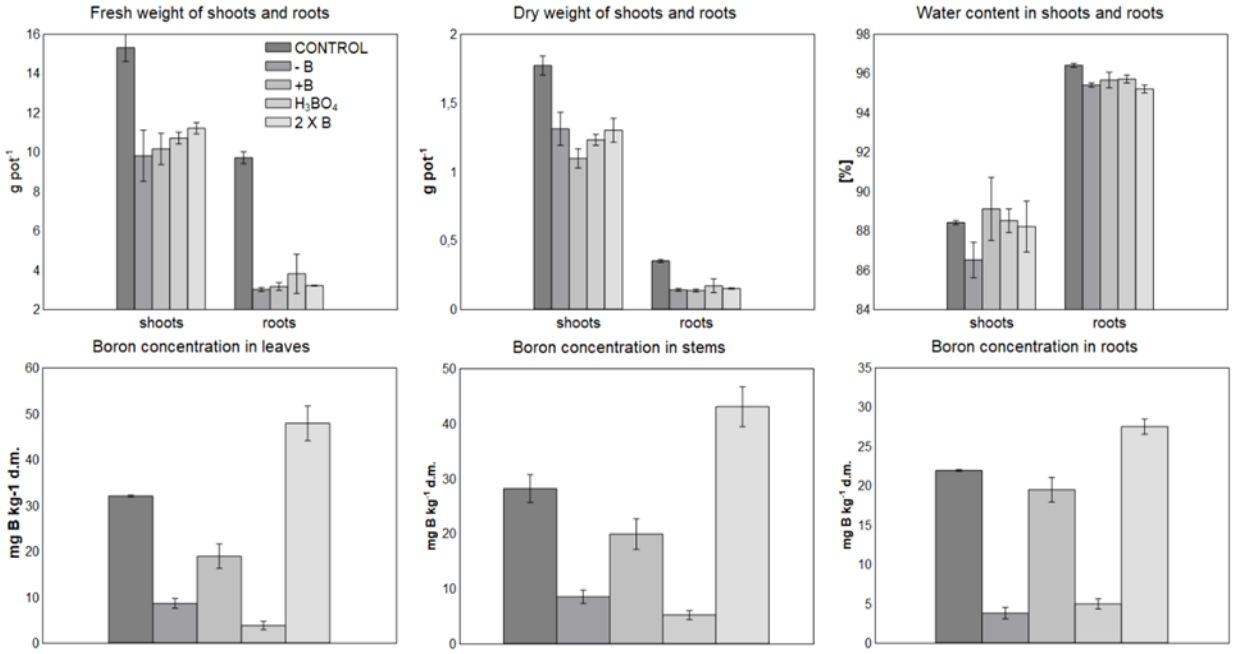

Figure 1. Comparison of the cucumber *Cucumis sativus* L. response to foliar application of different boron forms, hydroponics: CONTROL Hoagland solution, -B Hoagland solution without B, foliar applied: +B SiO_2 nanoparticles with B, boric acid, 2xB SiO_2 nanoparticles with doubled dose of B.

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Cellulose Hybrid Materials for Wound Dressing with Delayed Drug Release Properties

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Hybrid Material, Wound Dressing, Delayed Drug Release

Proper wound management is of paramount importance in order to prevent wound infection and to facilitate the wound healing process. Traditional wound dressing materials such as cotton or linen act as a physical barrier by covering the wound. In doing so, they lower the chance of wound infection occurring. However, these traditional wound dressing materials lack inherent antibacterial properties, nor do they enhance wound healing. The emergence of nanotechnology has led to methods being explored to develop so called "active" wound dressing materials, possessing antibacterial properties or stimulating tissue regrowth. Nanocellulose has been of keen interest as potential wound dressing material due to its beneficial properties (e.g. biocompatibility, gas permeability, exudate removal). Unfortunately, like traditional dressing materials it leaks antibacterial characteristics. To imbue nanocellulose with antibacterial properties, efforts have been made to combine nanocellulose with traditional antibiotics. Without further modification, these materials typically show low retention of antibiotics, leading to rapid release into the wound environment. In order to control the release of antibiotics, attempts were made to incorporate biocompatible metal oxide nanoparticles with high affinity for antibiotics and other pharmaceuticals. In this way, a cellulose-based wound dressing material was produced permitting the daylight controlled release of the broad-spectrum antibiotic tetracycline [1]. Modifying a commercial bacterial

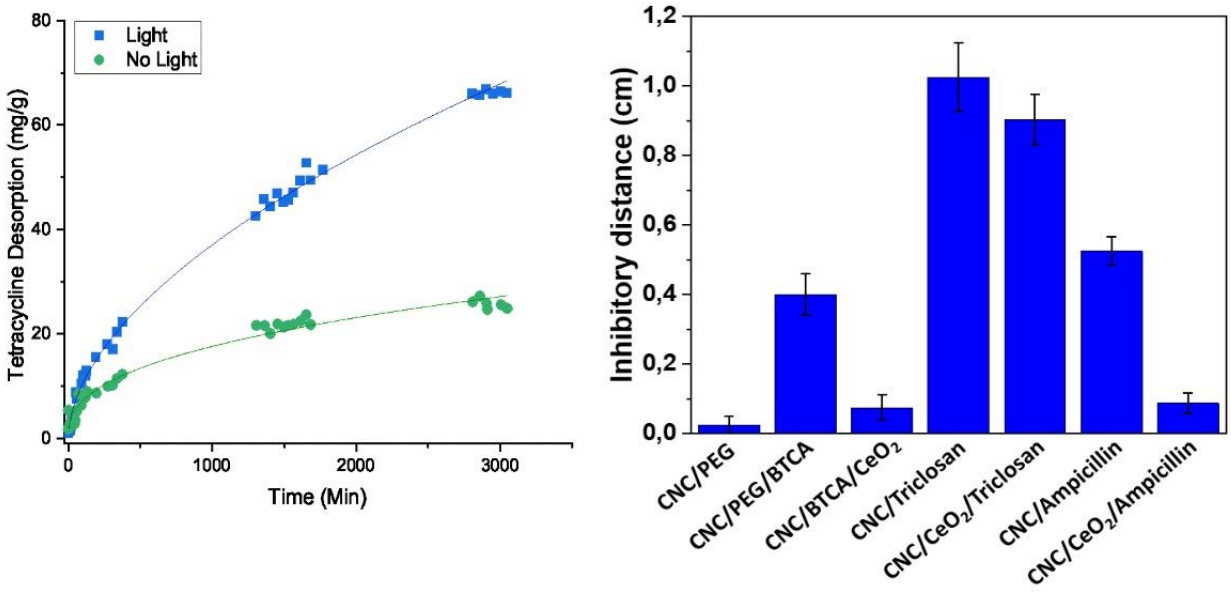

Figure 1. (a) Daylight influenced delayed drug release of the broad spectrum antibiotic Tetracycline. (b) Average inhibitory effect of Ampicillin/Triclosan in gel difussion tests, with or without CeO_2.

cellulose-based dressing material with metal oxide nanoparticles facilitated sustained release of Tetracycline [2]. Finally, a hybrid material was prepared for the controlled release of ampicillin [3]. The incorporation of metal oxide nanoparticles into nanocellulose-based materials offers a versatile approach to functional, biocompatible, hybrid materials capable of delayed drug release, which may be used as "active" wound dressings.

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The influence of excitation wavelength on the emission of europium(III) ions in phosphate silicate hydroxyapatite

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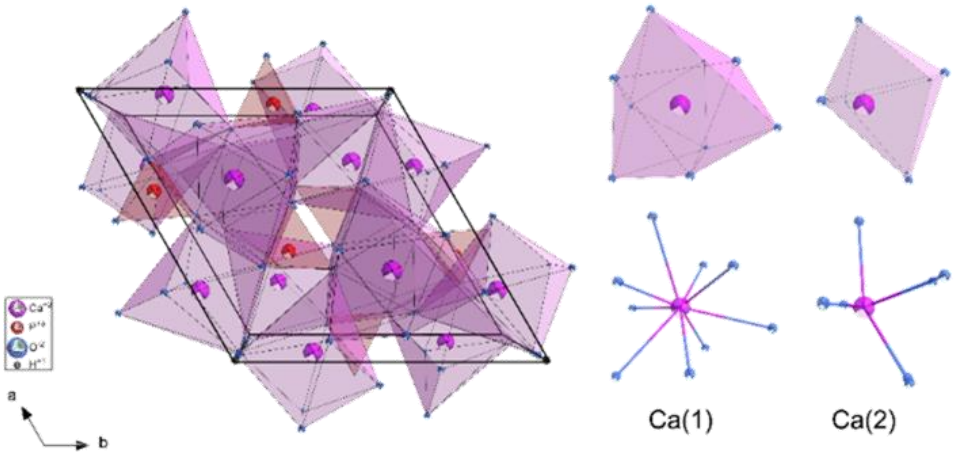
europium-activated inorganic phosphors, luminescence properties, spectroscopy

Synthetic hydroxyapatite (HAp; $Ca_{10}(PO_4)_6(OH)_2$) exhibits exceptional bioactivity and biocompatibility rendering it highly valuable in medical applications such as bioimaging. The HAp crystallizes in a hexagonal structure (space group *P6₃/m*). Furthermore, within the HAp structure, two distinct cationic sites can be identified – non-center-symmetrical Ca(1) and non-equivalent Ca(2). Doping with Eu^{3+} exhibit enhanced capabilities compared to organic optical probes. Additionally, within the anionic site, phosphate ions may be substituted by silicate anions, SiO_4^{4-}.

This study focuses on examining the influence of excitation wavelength on the emission of Eu^{3+} ions at the Ca(1) and Ca(2) sites within the phosphate silicate hydroxyapatite matrix. We prepared a series of materials with incremental silicate content and another series with variations solely in annealing temperatures. To characterize the morphology and chemical structure of the obtained materials, we employed techniques such as X-ray Powder Diffraction (XRPD), Scanning Electron Microscopy-Energy-Dispersive Spectrometry (SEM-EDS), Fourier Transform Infrared (FT-IR) spectroscopy, and Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES). Our study delved into the spectroscopic properties, including emission, excitation, and emission kinetics.

Fig. 1 Representations of the unit cell of calcium hydroxyapatite with the coordination polyhedra of the cations.



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Interaction of carbon-containing nanoparticles of smoke with various types of pollutants during their simultaneous exposure: physical chemical property and neurotoxicity

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war-derived air pollution nanohybrids, carbon containing smoke nanoparticles, FTIR, Raman spectroscopy, TEM, DLS, neurotoxicity

Due to extremely enhanced air pollution in connection with war in Ukraine, we faced environmental challenges that had not existed before. Because of war we have a large number of fires and explosions, so a significant number of various types pollutants enter the air at the same time - combustion products of wood, plastic, other materials, smoke nanoparticles, as well as nanoparticles of heavy metals. It can lead to a synergistic effect and the formation of complex nanohybrids containing both smoke nanoparticles and heavy metal ions that have significantly higher toxicity. In this work the author's approach to modelling such nanoparticles is proposed. We burned wood using laboratory device and received an aqueous suspension of smoke. After that, solutions of metal salts were added and incubated to obtain complexes.

UV-Vis, FTIR, Raman, luminescence spectroscopy, TEM microscopy, electron diffraction, DLS (dynamic light scattering) of the original aqueous suspension of poplar smoke and the mixture with copper ions were done to establish the possibility and nature of smoke particle formation. As result, a formation of the carbon particles with remains of organic molecules were detected in the air pollution from poplar, under interaction with Cu^{2+} ions, the sizes of particles increases in the dominant fraction from 140 nm to 240 nm, and for large aggregates up to 8 mm. FTIR spectra of poplar smoke have absorption bands related to wood combustion products, complete or partial oxidation of cellulose and lignin. The most toxic components of wood smoke are polycyclic aromatic hydrocarbons, aldehydes, benzopyrene, solid particles of various sizes, heavy metals. Neorotoxic property of the particles studied and discussed.

Funding

Project “War-derived air pollution nanohybrids composed of carbon-containing smoke nanoparticles and metal compounds: FTIR/Raman spectroscopic, fluorescent and membrane-active properties, their potential neurotoxicity and its prevention”. Project PAN.BFB.S.BWZ.380.022.2023.

Antibacterial activity of ZnO nanoparticles thin films

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coating, ZnO, antibacterial, sol-gel, thin film, dip coating

Nosocomial infections are prevalent complications among patients admitted to intensive care units, with reported incidences ranging from 5% to 10% in Europe and America [1]. These infections result from the overuse of antibiotics, leading to microbial resistance. This project aims to develop biocidal coatings to prevent microbial infections for surface detoxification and ventilation systems. In this context, the development of novel antimicrobial agents based on nanomaterials is currently of great interest in the biomedical field. Metal oxides have emerged as promising candidates [2], notably zinc oxide (ZnO), due to their multifaceted mechanisms in combating bacterial resistance.

ZnO garners significant attention as an appealing metal oxide material due to its biocompatibility, easy synthesis and cost-effectiveness [3,4]. In a recent study, we investigated the impact of the size of ZnO nanoparticles (NPs) in suspension on their antimicrobial activity. This investigation prompted us to explore the antimicrobial activity of ZnO NPs thin films. These thin films were synthesized using sol-gel and dip coating methods, with variations in sizes, preferential orientations, and roughness. Subsequently, their impact on antimicrobial activity was examined according to ISO 22196:2011. Our findings revealed that the antibacterial activity of ZnO NPs thin films is enhanced when the films are well-oriented preferentially along the (002) axis and when their size is smaller. Remarkably, these thin films demonstrated robust antibacterial efficacy, even at notably low precursor concentrations of 0.1 M. The main factors influencing the preferential orientation of thin films along the (002) axis and their particle size were identified as the precursor concentration and the length of the carbon chain in the synthesis solvent.

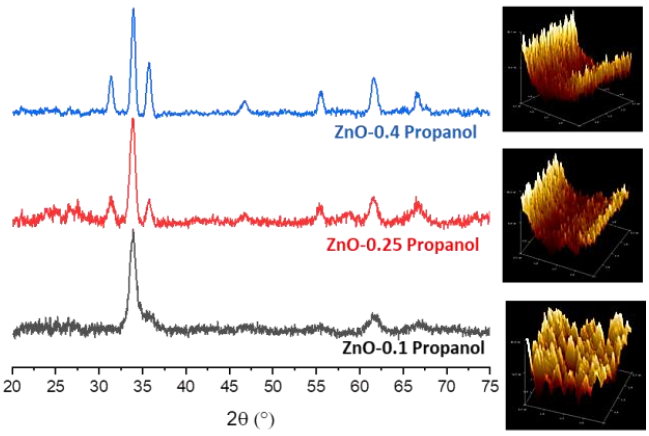

Figure 1 : Structural analysis using X-ray diffraction (XRD) of ZnO thin nanoparticles films with varying preferential orientations and their respective Atomic Force Microscopy (AFM) images

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Spectroscopic characterization of $NaYF_4$: Tm^{3+}/Pr^{3+} microcrystals showing concurrent emission in UV and NIR spectral ranges

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$NaYF_4$ microcrystals, VIS-to-UV up-conversion, VIS-to-NIR down-conversion

The optical spectroscopy of trivalent lanthanide ions has drawn attention since 1880s, owing to the fact that their robust energy levels stack up as a multi-step-ladder resembling structure. This remarkable feature allows them to absorb photons and manage their energy via radiative and non-radiative f-f transitions. Depending on the mechanism parameters, e.g. sufficiently long lifetimes of excited states, the emitted photons could be lower or higher in energy than the input photons. Furthermore, the energy conversion processes are highly likely to occur simultaneously, which results in emissions observed across various spectral ranges, i.e. ultraviolet (UV), visible (VIS), and near-infrared (NIR). Not to mention, the ability to predict the emission bands of trivalent lanthanide ions when incorporated into low phonon energy host matrices (e.g., $LiYF_4$ or $NaYF_4$) facilitates the design of lanthanide-based bimodal optical materials. These advancements hold promise for the development of state-of-the-art photovoltaic instruments, optical amplifiers, telecommunications systems, and theranostic devices [1].

Recently, our scientific focus has shifted towards fluoride matrices doped with Tm^{3+} ions, known for exhibiting numerous emission bands in the UV, VIS, and NIR spectral regions. Their robust electronic structure enables multiple energy migration processes, such as up-conversion or quantum cutting. While pairs like Tm^{3+}/Yb^{3+} and Tm^{3+}/Er^{3+} have been extensively studied for emission enhancement [2], [3] information on the Tm^{3+}/Pr^{3+} pair remains scarce. Therefore, we have chosen to explore it in more detail. Microcrystalline $NaYF_4$ samples synthesized via solid-state techniques were characterized under VIS laser radiation excitation. The VIS-to-UV up-conversion emission, Stokes VIS-to-VIS emission, and VIS-to-NIR down-conversion were collected and analyzed. Additionally, luminescence decay curves were recorded for the selected emission bands. These findings contribute to a better understanding of photon management processes in Tm^{3+}/Pr^{3+} co-doped materials, which is crucial for designing devices that utilize concurrent emission in both UV and NIR regions.

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Funding

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Alkali-free-based bioactive glass compositions and devices for the most demanding applications in healthcare, bone regeneration and tissue engineering

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alkali-free bioactive glasses; scaffolding/porous structure; therapeutic ionic substitutions; antimicrobial efficiency; osseointegration.

The commercially available bioactive glasses such as the 45S5 Bioglass®, and other high alkali-containing compositions, suffer from poor thermal stability, inappropriate dissolution rates and extreme high pH values. Such high alkaline conditions do not naturally occur in the human body, are likely leading to ionization of proteins, change their functions, and induce cell necrosis. The high sodium contents of the 45S5 Bioglass® and the like compositions, make the fabrication of porous 3D scaffolds difficult, confer them poor sintering ability, and turn the materials cytotoxic. These main drawbacks have driven our research efforts towards developing new and better performing materials *in vitro* and *in vivo*, while enhancing the fabrication of 3D porous scaffolds with tailor-made porous structures to promote osteointegration. Another alternative/complementary approach is the development of bioactive glass wool microfibers enjoying of shape-adaptability to fill any bone defect as a kind of universal ready to scaffold. All the relevant features strongly depend on a number of interrelated factors that need to be well compromised, including the chemical composition and glass structure, which determine the biocompatibility, the degradation rate, and the easiness of processing (shaping and sintering), or fibre drawing the molten material. This presentation provides an overview about the motivations behind the development of a new series of alkali-free bioactive glass compositions based on bioactive minerals such as Diopside (Di), Fluorapatite (FA) and Tricalcium Phosphate (TCP), as well as their further compositional refinements towards obtaining the desired sets of well-balanced overall properties for the most demanding applications in healthcare, bone regeneration and tissue engineering.

Photocatalytic and antibacterial properties of H_2O_2-sensitized TiO_2

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peroxide-assisted sol-gel method, titanium dioxide, hydrogen peroxide, catalyst

The search for advanced and safe approaches to combat pathogens is a serious concern for public health protection. Titanium dioxide is known for its efficacy in self-cleaning and self-sterilization against viruses, fungi, and bacteria. TiO_2 is activated by UV light and relies on the limited UV content in the solar spectrum and is impractical indoors where UV is filtered by glass or must be activated by artificial lighting causing potential human health risks.

In this study to enable activation using visible light, the production of titania contained its treatment with hydrogen peroxide. The modified route of the synthesis introduced changes of titanium dioxide in the electronic (narrowing the band gap) and chemical structure (by introducing additional oxygen (peroxide and superoxide) groups). Then, H_2O_2-sensitized TiO_2 was used to decompose methylene blue which displayed its efficiency when activated by the visible light but also in the absence of irradiation. The potential of H_2O_2-sensitized TiO_2 against *Enterococcus faecalis* and *Escherichia coli* species, chosen for their clinical relevance, was also tested. The results shows that oxidative behavior of H_2O_2-sensitized TiO_2 holds promise not only for visible light photocatalyst but also for continuous cleaning processes carried out in the dark, particularly in medical settings, where certain bacteria may persist under photocatalytic conditions and recover in the absence of light. Hence, this research follows the trend of innovative strategies in medical sanitation and infection control.

ZnO-based nanoparticles for biomedical applications

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oxides; nanoparticles; fluorescence labels; MRI; cancer

ZnO-based nanoparticles activated with selected rare earth (RE) ions were successfully applied by us as fluorescence markers allowing early detection of cancer [1]. For example, an effective trafficking of these markers to the areas of lung cancer was observed, whereas surrounding tissue was impermeable for nanoparticles. The data obtained confirm 100% selectivity of the method.

The following experiments proved that the same markers can be used as contrast agents in MRI and for transporting a given medicine to area of tumor. A directed therapy turned out to be possible, proving theranostic properties of the markers.

ZnO particles are not stable in body fluids. This increases safety of the method (we avoid long time accumulation in the body) and opens chances for new applications. We tested recently use of ZnO particles for micro-elements supplementation.

For fluorescence labelling efficient emission of markers should be observed. It will be explained why doping with selected RE ions results in a relatively efficient photoluminescence and the method used by us to determine stability of markers will be described.

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Gold Nanoshells Decorated with Silver Sulfide Quantum Dots as Novel Nanoplatforms for Theranostic Applications

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silver sulfide quantum dots, gold nanoshells, theranostics

In our investigation, we are dedicated to crafting a novel colloidal hybrid material composed of gold nanoshells and silver sulfide quantum dots. By melding a fluorescent emitter with a metallic nanoparticle, we've successfully heightened fluorescent emission within the near-infrared spectrum. Through precise control of the emitter's proximity to the metallic surface using a silica layer, we can delve into the kinetics of the emission process, a pivotal aspect in determining the optimal parameters for a nanomaterial.

In essence, the fusion of gold nanoparticles with quantum dots presents a robust platform for theranostics, facilitating concurrent imaging and therapy with heightened sensitivity, specificity, and precision.

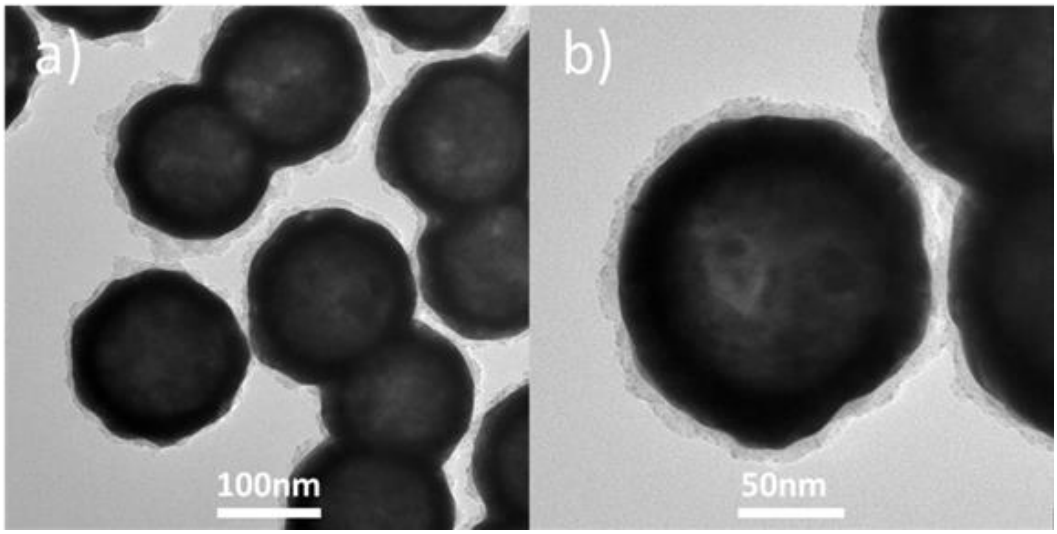

Figure 1. TEM images of gold nanoshells covered with a silica spacer layer and attached silver sulfide quantum dots.

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Funding

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Hydrogel loaded with nanostructures based on superparamagnetic particles and hydroxyapatites for local delivery of anti-fungal and anti-inflammable drugs

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hydrogel, nanoparticles, drug delivery, anti-inflammatory, anti-fungal

Hydrogels are widely used in medicine due to their facile loading with many different biologically active molecules and easy synthesis. They offer prolonged and spatial control for releasing different therapeutic agents in different various tissues. In our study, we focused on the preparation of hydrogels as drug carriers for the treatment of wounds, including gum disease lesions. The proposed hydrogel loaded with hydroxyapatite and superparamagnetic iron oxide nanoparticles (SPIONs) was proposed to be a novel way to deliver anti-inflammatory and antifungal drugs. The nanoparticles were synthesized using a co-precipitation technique and incorporated into the hydrogel before being cross-linked together with anti-inflammatory and antifungal drugs. The hydrogel can be designed in a specific shape and size and can be 3D printed, making it a promising material for dental applications, offering prolonged drug release, biocompatibility and the ability to carry different therapeutic agents. Drug release was studied by UV-vis spectrometry. The effectiveness of heating the hydrogel with SPION was investigated using magnetic hyperthermia. It was found that by loading SPIONs into the polymeric network of hydrogel, it was possible to increase the gel temperature up to 42 °C by means of an alternating magnetic field while improving drug release, while the loading of hydroxyapatites enables prolonged drug release.

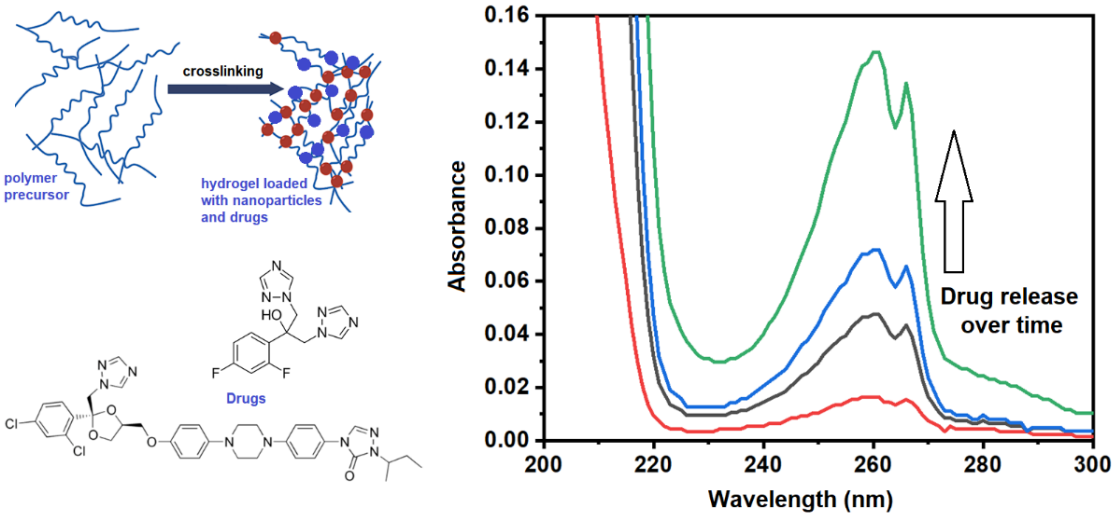

Figure 1. Schematic diagram of hydrogel and the results on the drug releas using UV-vis spectrometry.

Functionalized silsesquioxanes with cage architecture as versatile building blocks in chemistry and biomaterials engineering

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Double-decker silsesquioxanes (DDSQs) and polyhedral oligomeric silsesquioxanes (POSSs) occupy an indisputable place among the group of functionalized siloxane-based compounds and find the applications in various fields, including hybrid materials [1], coordination chemistry [2], catalysis [3], etc. They throw light on the development of molecular and macromolecular organosilicon chemistry concepts.

While the use of POSS in medicine has been known for years, DDSQ has not been widely exploited in this context so far. DDSQs can be used as building blocks for composited with polyvinyl alcohol (PVA) creating potential biomaterials applied for skin regeneration. The method of preparation and characterization of the hybrid biocomposites based on double-decker silsesquioxanes (DDSQs) functionalized by methacrylate derivatives and polyvinyl alcohol (PVA) will be presented (Figure 1). The resulting biomaterials fulfill the requirements for potential skin regeneration applications. Human fibroblasts growing on prepared hybrid composites are characterized by proper spindle-shaped morphology, proliferation and activation status similar to control conditions (cells cultured on PVA), as well as increased adhesion and migration abilities. The obtained results suggest that the prepared biomaterials could be used as a factor supporting the wound healing process [4, 5].

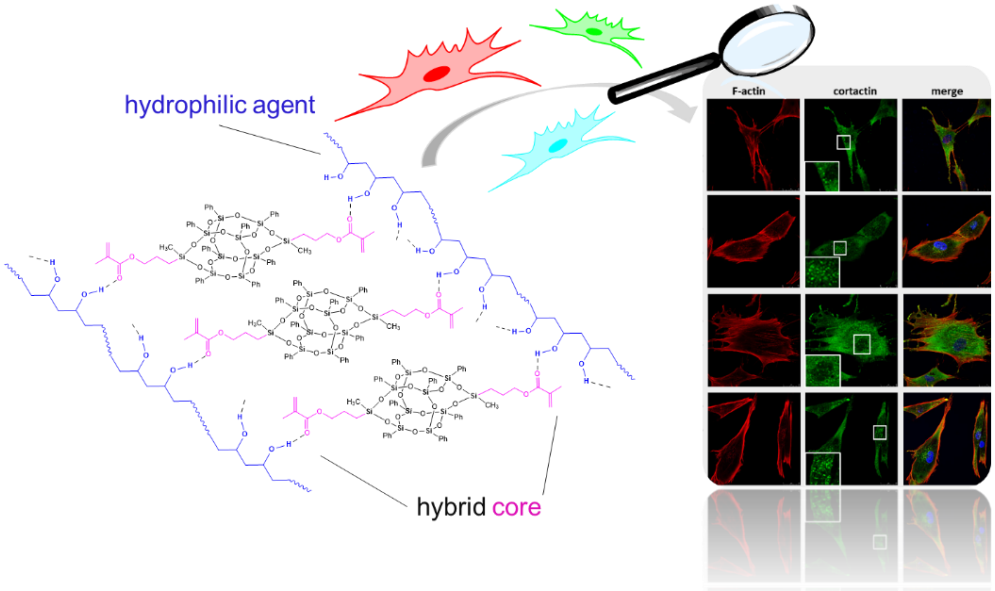

Figure 1. Idea of the hybrid biocomposite based on DDSQ/PVA system.

Funding

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Exploiting the Full Potential of Surface Plasmon Resonance: Beyond Sensorgrams and Kinetics to Reflectance Spectra and Surface Layer Characterisation

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Surface Plasmon Resonance, Fresnel Equations, Biophysics

Surface Plasmon Resonance [SPR] has been widely used in biology, providing biophysical data such as affinity, kinetics, and thermodynamics of biological ligands. The main data output has been in the form of a sensorgram, which measures the rate of change in mass at the sensor surface, in terms of the angular change in the position of the Peak Minimum Angle. However, there is a much more powerful approach possible from analysis of the full Reflectance Spectrum collected as part of the SPR data collection process, facilitating the measurement and characterisation of surface layers formed on the sensor surface.

The advanced level of analysis available by treatment of the full Reflectance Spectrum of SPR via the Fresnel Equations enables the determination of the transmittance and reflectance properties of the surface coatings, through the Refractive Index and the Extinction Coefficient. This extends the utility of SPR beyond the biological field to materials and coatings, providing a dynamic insight into the mechanism of layer formation.

This presentation will present a brief overview from the literature of the different possibilities now available in surface layer analysis with respect to biophysics and surface layer characterisation in a wide range of bio-related applications in material sciences.

Moreover, our own data related to the novel application of SPR in studying hydrogen interactions with a sol-gel surface in the context of green energy technology will be presented.

Funding

The research was supported by the National Center for Research and Development in Poland under the Small Grant Scheme (SGS) project entitled 'Improving the Efficiency of Hydrogen Storage Vessels through Novel Oxide Coatings HyStor NOR/SGS/HyStor/0306/2020-00' under the Programme for 'Applied Research', financed through the Norwegian Financial Mechanism.

Application of sol-gel materials in bioenergy technology: sealing high-pressure hydrogen tanks

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Technologies related to renewable energy, including those utilizing hydrogen as an energy carrier, are becoming increasingly important in reducing greenhouse gas emissions. Hydrogen as a fuel of the future has the potential to become a key element in the energy transition towards a more sustainable and cleaner economy. The advantages of this solution include its low-emission production, universality, and high energy density. However, hydrogen is not without its drawbacks, and challenges associated with its production, storage, distribution, and utilization exist. Focusing on the challenge of hydrogen storage, one issue is reducing hydrogen permeation through materials. Hydrogen has the ability to permeate through certain materials, leading to fuel loss from the tank. Prolonged storage can result in losses. This work presents sol-gel coatings that reduce hydrogen permeation by 30-40% at low pressure and up to 68% at high pressure.

Polyoxometalates as molecular models for mineral nanoparticle – protein interactions

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POM-peptide complex, crystal structure, hydrogen bonding
redox reaction mechanisms, anti-viral activity

Oxygen is the most abundant element in the earth crust and primary constituent of minerals in soils and waters. Sand minerals such as silicon oxide and metal oxides have been through the whole history of life on Earth been generated via weathering of the primary silicate minerals. They are thus necessarily biocompatible as life has emerged and was developing in their constant presence.

Variation in size of the mineral nanoparticles (NP) makes direct structural investigation of their interaction with biomolecules, in the first hand, proteins, challenging forcing researchers to rely on indirect characterization methods. In our studies, we proposed to apply polyoxometalate species (POM) in complexes with oligopeptides as molecular models for revealing bonding modes and reaction mechanisms of NP. The influence of such factors as polarity on M-O bond, thermal pre-history of solution [1], peptide chain length and hydrophilicity/hydrophobicity [2], acidity and salinity of the media [3] on the structure and bonding in POM-peptide complexes have been investigated.

Application of POM models in explanation of the anti-viral activity in combination with NMR studies brought light on possible binding modes used by NP in blocking functional viral proteins [4].

Direct insight into redox nanozyme activity of NP was obtained by structural investigation of tryptophan and related peptide complexes with POM. Evidence for direct transformation processes not necessarily involving reactive oxygen species has been obtained permitting to trace complete reaction mechanisms [5].

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Assessment and Development of a Core-Shell SPION-Based Targeted Nanoparticle Therapy for Atherosclerosis Treatment

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nanoparticle therapy, targeted drug delivery, atherosclerosis, biocompatible materials

Current therapeutic approaches for atherosclerosis are limited by their systemic side effects, lack of specific targeting capabilities, and are primarily preventative in nature. At the present time, there is no direct pharmacotherapy available to fight atherosclerosis at the sight of the lesion. Developing a therapy that precisely targets the point of injury could significantly enhance therapeutic efficacy while reducing the negative impacts associated with current treatment standards. The aim of this preclinical stage one study is to develop and synthesize a targeted core-shell superparamagnetic iron oxide (SPION) based nanoparticle therapy to enhance therapeutic efficacy while also minimizing adverse effects of treatment. Our methodological framework employs the chemical synthesis of a core-shell SPION-based nanoparticle with an emphasis on fine-tuning their physical attributes, such as size, shape, and surface modulation with potential targeting moieties. These nanoparticles will undergo a comprehensive analysis of their physical properties, drug loading efficacy, and targeting specificity to further characterize these particles. Early-stage assessments will involve numerous chemical and physical tests for pharmacokinetic analyses, aiming to select the most effective.

As this is a stage one preclinical study, the results are forthcoming and are yet to be reported. However, this study is designed to synthesize and assess the nanoparticle's shape, size, loading potential, pharmacokinetics, and therapeutic potential to reduce atherosclerotic plaque burden. The key findings of our study will be presented at the upcoming conference. This research seeks to bridge nanotechnology with contemporary medicine, aiming to advance the field of nanotechnology by synthesizing a novel core-shell SPION-based therapy for atherosclerosis. Our dedicated team is working to offer a promising new approach to the treatment of atherosclerosis, one which may potentially overcome the limitations of currently available therapies and improve patient outcomes through an interdisciplinary approach, careful design, and evaluation.

Antimicrobial Coordination Polymers: From Self-Assembly to Biomaterials

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metal-organic frameworks, hybrid biopolymers, antibacterial properties, functional materials

To address increasing antimicrobial resistance, the search for new bioactive molecules and sustainable materials is currently in high demand. This presentation will highlight our recent research on the self-assembly synthesis, crystallization methods, structural features and applications of a wide diversity of functional metal-organic architectures, including bioactive metal-organic frameworks (MOFs), coordination polymers (CPs), metal complexes and derived materials with potent antibacterial and biofilm inhibition properties [1-3]. The following topics will be discussed.

A. Self-assembly generation and structural diversity of silver(I) and copper(II) coordination polymers derived from carboxylic acids, aminoalcohols and other ligands.

B. Application of these compounds as efficient antimicrobials against different types of Gram-positive and Gram-negative bacteria, bacterial biofilms, and fungi.

C. Design of CP-doped biopolymer films based on soybean oil, potato starch, agarose or cellulose.

D. Antibacterial and biofilm inhibition activity of the obtained biopolymer films as a function of dopant type and loading, biopolymer matrix, and metal ion release rates.

This multidisciplinary study expands the antimicrobial use of bioactive coordination polymers and hybrid biopolymer materials obtained from renewable and low-cost biofeedstock sources.

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The mechanical properties, release of fluoride ions and thermographic characteristics of specific dental materials (Boston – composite and Twinky Star – compomer) utilized in primary dentition - an in-vitro evaluation

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fluoride ions release, microhardness, Young's modulus, thermographic investigation, dental materials

The study was conducted in order to evaluate and compare the mechanical characteristics, release of fluoride ions and temperatures produced during the polymerization process of specific dental materials (Twinky Star, Boston) utilized for cavity restoration in primary teeth. The research encompassed the assessment of various factors such as physical attributes (density), mechanical properties (Vickers hardness (HV), Young's modulus (E)) of dental tissues (enamel, dentin), and dental restorations, as well as the measurement of the highest temperatures attained during the polymerization of materials.

Two different groups of dental materials, compomer (Twinky Star) and microhybrid composite (Boston), underwent testing. To prepare the samples, a specific form was utilized, with a diameter (d) of 6 mm and a height (h) of 2.5 mm. The composite material was cured for 20 seconds as per the manufacturer's guidelines, while the compomer was cured for 40 seconds using the Bluephase Style 20i polymerization lamp from Ivoclar Vivadent in Schaan, Liechtenstein. The density of dental fillings was assessed by calculating the weight-to-volume ratio. To determine the weight, a RADWAG® PS 1000/C/2 laboratory analytical balance with a precision of 0.001g was utilized. Additionally, the geometric parameters of each sample were measured using a Mitutoyo micrometer. Mechanical tests, including the measurement of microhardness and Young's modulus, were conducted on both dental filling samples and tissues from deciduous and permanent teeth. The CSM MicroCombi Tester™ microhardness tester was employed to carry out the tests, allowing for the determination of Vickers microhardness and Young's modulus values. Lastly, a thermal imaging camera (FLIR ThermaCAM P640) was used to measure the maximum temperatures resulting from the irradiation of samples from both groups. Over a period of 7 weeks, the Boston and Twinky Star products were analyzed for the release of fluoride ions into four different solutions: artificial saliva with pH levels of 4.5, 7.0, and 7.5, as well as deionized water. This analysis was conducted at specific time intervals using an ORION 9609 ion-selective electrode from Thermo Fisher Scientific Co., based in Waltham, MA, USA.

Table 1 presents the average density, along with the corresponding standard deviation in grams per cubic centimeter, as well as the Young's modulus E in gigapascals and Vickers hardness values HV. The temperature achieved during the third second of the material's polymerization process (composite) is depicted in Figure 1.

Table 1. Mechanical and physical properties of tested dental materials

	Average density $\rho \pm SD$ [g/cm^3]	Young's modulus E [GPa] ± SD	Vickers microhardness [HV] ± SD
Boston	1,815 ± 0,0816	16,93 ± 0,35	68,76 ± 1,94
Twinky Star	1,634 ± 0,0830	18,96 ± 1,90	79,90 ± 5,01

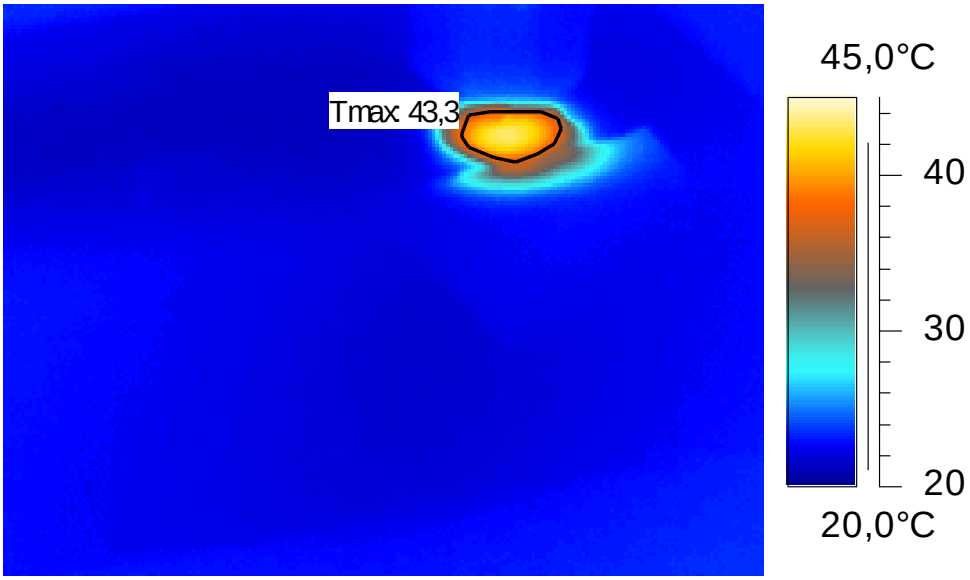

Figure 1. Maximum temperature obtained in the 3rd second of composite polymerization

During the polymerization process, Boston reached a peak temperature of 48.6°C, while Twinky Star surpassed that with a maximum temperature of 63.1°C. It is important to highlight that the critical temperature for dental pulp is 42°C. At the onset of the study, the release of fluoride ions from both dental materials reached its peak when immersed in deionized water (Boston – 0,139 ppm and Twinky Star – 0,103 ppm). Both materials exhibited similar levels of fluoride ion release in artificial saliva at pH 4.5 and 7.0.

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Synthesis of Mn-doped TiO_2 Nanoparticles

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synthesis of nanoparticles, doping, advanced materials, biocompatible nanozymes

The usability of metal oxide nanoparticles has expanded into new fields over the past decade. Particular attention has been focused on biocompatible metal oxides in medical applications [1] including encapsulation of cells [2]. Titanium and manganese oxides are very valuable in this aspect, however, their combined properties have not been fully investigated.

The application of NP in medicine has high demands both in enhancing natural processes such as wound healing and in enabling imaging of the treated regions [3]. In this study, we aimed to produce Mn-doped TiO_2 nanoparticles as potentially highly biocompatible nanozymes, applying solvothermal synthesis and a novel hydrothermal method. In both approaches, nanoparticles differing in crystallite size, oxidation-reduction potential, solubility and photocatalytic properties were obtained.

Pre-functionalized polyanionic polystyrene nanospheres were used to demonstrate the applicability of nanoparticles for model encapsulation. The Mn-doped TiO_2 nanoparticles effectively encapsulated them, simultaneously revealing differences in the encapsulation process. Further encapsulation of human cells showed similar biocompatibility and high cell viability in vitro for both types of materials.

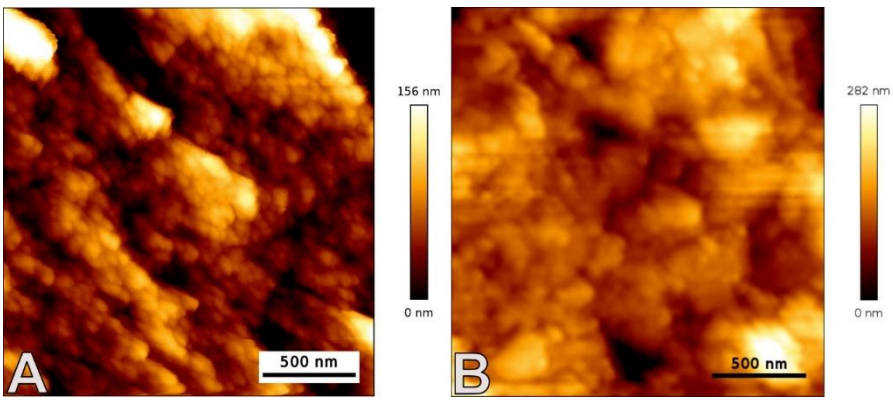

Figure 1. Atomic force microscope (AFM) image of Mn-doped TiO_2 nanoparticles after solvothermal synthesis: a) After thermal treatment b) Before thermal treatment

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Synthesis, morphology and optical properties characterization of Zn_2GeO_4:Mn pH-size dependent nanomaterials

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ZGO, advanced functional materials, persistent luminescence, biomedical applications

Zn_2GeO_4:Mn (ZGO:Mn) is one of a materials known from its efficient persistent luminescence properties. Such materials are capable of storing excitation energy in crystal structure defects, inner traps such as holes or electrons, whereas once excited can remain luminescence properties after source of the excitation has stopped [1]. This interesting property opens up the potential use of these type of materials for biomedical applications, e.g., bioimaging, therefore the crucial issue is the proper synthesis approach to ensure the nanometer size and monodispersity of the obtained ZGO:Mn materials [2].

In this work, with the use of hydrothermal, microwave assisted synthesis, six different nanomaterials based on the same Zn_2GeO_4:Mn matrix have been obtained. Each synthesis was carried out for different pH values, i.e. 6.0; 7.0; 7.5; 8.0; 8.5; 9.5, respectively.

Morphology of the synthesized ZGO:Mn have been characterized by the transmission electron microscopy (TEM). On the basis of the measured images, size distributions have been calculated. The crystal structure has been confirmed by X-ray powder diffraction (XRD) method. Optical properties (excitation and emission spectra) have been investigated via spectrofluorometer.

Use of various pH values during the synthesis process resulted in nanoparticles that differs in size values, what has been confirmed via measured size distribution histograms. The luminescence properties due to the doping of manganese (II) ions was confirmed by spectroscopic measurements. Currently, the first attempts are planned to characterize the persistent luminescence properties of the obtained functional materials, and towards surface functionalization.

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Metal-substituted calcium hydroxyapatite: synthesis and application in the production of cosmetic products

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calcium hydroxyapatite, metal-substitution effects, cosmetic products, antibacterial properties

Calcium hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$, CHA) is a biocompatible and biodegradable substance with great promise for bone regeneration. Besides, CHA has attracted attention due to the possibility of using it in the development of new cosmetic products. Metal-substituted CHA is showing antibacterial properties. In addition to showing antibacterial properties, metal-substituted CHA can function as an ultraviolet (UV)-protecting agent in cosmetics.

In this study, freshly precipitated metal-substituted α-tricalcium phosphate (α-TCP) was used as a precursor for the synthesis of zinc-, copper-, or iron-substituted CHA samples under hydrothermal conditions. The amount of the transition metal ions in the samples corresponded to the Ca substitution level of 0.8 – 1 mol%. The synthesis procedure could be briefly described as follows: 0.3 g of metal-substituted α-TCP powders were placed in 90 mL vessels to which 20 mL of water were added. The sealed vessels were placed in an oven heated up to 200 °C. After the initial heating for 30 min (to reach the treatment temperature), the hydrothermal treatment was applied for 16 h. Subsequently, the vessels were cooled down to room temperature and the samples were filtered, washed with ethanol and acetone, and dried at 50 °C overnight.

Powder X-ray diffraction data for synthesized samples were collected using a Rigaku MiniFlex II diffractometer that emitted Ni-filtered Cu Kα radiation and worked in Bragg-Brentano (θ/2θ) geometry. Infrared spectra in the range of 4000−400 cm^{-1} were recorded using a Bruker ALPHA ATR spectrometer, while the sample morphology was determined using a Hitachi SU-70 field-emission scanning electron microscope (FE-SEM). Samples were prepared for elemental analysis by dissolving them in 5% nitric acid and diluting the solution with deionized water. Analysis was performed on Perkin Elmer Optima 7000 DV ICP-OES system.

The production of a cosmetic product consisted of three stages: (a) preparation of the oil phase; (b) preparation of the aqueous phase; and (c) connecting temperature-sensitive components. The oil phase was melted in a separate beaker with slow stirring and heating of the

raw materials of oil phase up to 75 – 80 °C. The aqueous phase raw materials were also combined by stirring and heating to 75-80 °C. Both phases, after the ingredients had been evenly mixed and reached a uniform temperature in the range of 75-80 °C, were combined by pouring the oily phase into the aqueous phase. After joining, homogenization was performed at 2000-3000 RPM for 2 min, maintaining the temperature in the range of 75-80 °C. Then, the mixture was allowed to cool to 35°C while stirring and the temperature sensitive ingredients were added. The phases were combined by homogenization at 2000-3000 RPM for 2 min.

It was determined that the introduction of Zn^{2+}, Cu^{2+} and Fe^{3+} ions to the hydrothermal synthesis solution had a significant impact on the hydrolysis process of α-TCP. By applying metal cations as controlling agents for hydrothermal synthesis, the morphology control of CHA was achieved. Finally, the *in vitro* analysis of cytotoxic and antimicrobial properties of metal-substituted CHA samples and fabricated cosmetic products were also investigated.

Additive manufacturing of stimuli-responsive hydrogel pharmaceuticals for controlled drug delivery

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drug delivery systems, hydrogels, additive manufacturing technologies, controlled drug release, mechanical properties

The value of customized medicine has increased significantly in recent years, especially in the context of orally administered pharmaceuticals, where the important aspects are choosing the right dose of the active substance for a particular patient and delivering it to a target place [1]. Through the implementation of additive manufacturing technologies, medications can be precisely tailored according to the required specifications. In addition, the use of appropriate materials enables the controlled release of the drug. Hydrogels are one of the materials under consideration for this kind of application [2].

Hydrogels are highly hydrated porous materials composed of networks of hydrophilic natural or synthetic polymers formed by physical covalent or non-covalent cross-linking. In their structure, they possess the ability to absorb and retain significant amounts of liquids. They are characterized by their soft, flexible structure, exhibit bioactive properties, and have the potential to be both biocompatible and biodegradable. Additionally, most hydrogel materials also stand out for having the capacity to modify their properties in response to external stimuli. Their versatile properties make them applicable in a wide range of areas, including biomedical fields (e.g., drug delivery systems, wound healing, tissue engineering, regenerative medicine, implants, prosthetics, biosensors) [3], [4].

This study presents the results of research conducted on a hydrogel drug delivery system based on 5% sodium alginate (Sigma Aldrich, USA), ionically cross-linked with calcium chloride (Avantor Performance Materials Poland, Polska) in concentrations 0.1M and cross-linking time 10 minutes. Additionally, to customize pharmaceuticals, additive manufacturing technology using 3D bioplotter BioX (Cellink,USA) was employed to fabricate a medication with a precise amount of the active ingredient. The tested active substances were ibuprofen and diclofenac sodium, each at a concentration of 5%, and 10%. The fabricated drug carriers were evaluated for mechanical properties (uniaxial compression test, Meltter-Toledo S210 Seven Compact (Greifensee, Switzerland)) and controlled release of the active substance in vitro in simulated the gastrointestinal tract in solutions with pH values of 2, 6.5, 7 and 7.5. The kinetics of drug release was examined spectrophotometrically (GENESYS 10S UV-VIS spectrophotometer (Thermo Fisher Scientific, USA)) in 5, 10, 15, 20, 25, 30, 45, 60, 90, and 120 minutes.

The compression test showed that the amount of active ingredient contained in the carrier influences the decrease in the value of elastic modulus Ec (17.4 kPa for the carrier without drug, 13.2 kPa for 5%, and 7.8 kPa for 10% drug content). Research on the kinetics of the release of active substances, on the other hand, indicated that the highest level of drug is released at pH 6.5 (450 μg/ml) and the smallest amount is released in an environment of pH 2 (119 μg/ml) for both 5% and 10% drug content in the carrier. The reason for this reaction is that the hydrogel structure shrinks in acidic environments, which prevents the medicine from releasing from the carrier. On the other hand, the structure swells in neutral and alkaline environments, causing the drug molecules to disperse into the environment due to relaxation of polymer bonds. A pharmaceutical with those characteristics can be used to simultaneously release the drug into the intestines, where the pH is between 6.5 and 7.5, likewise protect it from the stomach's acidic environment.

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The expression profile of differentiation antagonizing non-protein-coding RNA (lncDANCR) in human bone marrowderived stem cells (BMSCS) – analysis during osteogenesis influenced by silicate phosphate hydroxyapatites co-doped with Li^{+}, Eu^{3+}, and Gd^{3+} ions

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theranostics' biomaterials, bone regeneration, non-coding RNAs, multipotent stromal cells

Osteogenesis is a complex process orchestrated by multiple cellular and molecular actors, among which non-coding RNAs (ncRNAs) play crucial roles. They regulate various aspects of bone formation by modulating the expression of genes involved in cell differentiation, proliferation, and apoptosis [1], [2]. In our research, we focus on the importance of ncRNAs in the finely tuned regulation of osteogenesis driven by biomaterials. Recently, differentiation antagonizing nonprotein coding RNA (lncDANCR) has gained attention as a significant regulator of osteogenic differentiation. The molecule is known to inhibit the differentiation of mesenchymal stem cells (MSCs) into osteoblasts, highlighting its potential as a therapeutic target for enhancing bone regeneration and treating osteoporosis [3].

In the current study, we were interested in the influence of theranostic biomaterials, i.e., silicate phosphate hydroxyapatites co-doped with Li^{+}, Eu^{3+}, and Gd^{3+} ions on the lncDANCR expression profile in human bone marrow stem cells (BMSCs) during osteogenic differentiation. The cells used for the experiment had confirmed multipotency (SCC034, Merck/Sigma-Aldrich, Poland) and underwent osteogenesis. Transcript levels were determined using RT-qPCR technology. The lncRNA DANCR expression was compared with mRNA levels for RUNX-2, i.e., a transcriptional factor that serves as the master regulator of osteogenesis. Additionally, alongside the lncDANCR expression profile, several small non-coding RNAs were determined, including miR-7-5p, miR-17-5p, miR-21-5p, miR-30a-5p, miR-106a-5p, miR-124-3p, miR-125-5p, miR-320-3p, miR-410-3p, miR433-3p.

The analyzed expression profile shows us complex molecular networks involved in bone formation and remodeling guided by theranostics' biomaterials. Understanding how

lncDANCR, RUNX-2 expression, and several miRNAs interact and regulate these processes can provide valuable insights into optimizing biomaterials for enhanced bone regeneration and therapeutic applications.

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Stability Controlling of L-arginine- and L-nitroarginine Functionalized Graphene Oxide

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Nowadays, the field of 2D materials continues to evolve rapidly due to their unique physicochemical properties. In particular, there has been considerable emphasis on graphene oxide (GO) which is a derivative of graphene obtained by oxidizing graphite layers [1]. Moreover, the functionalization of GO enhances its application potential across various fields such as drug delivery, bioimaging, catalysis, sensing etc. [2].

In this work, we focus on electrochemical exfoliation of GO and its functionalization with amino acids (AA), namely L-arginine (L-Arg) and L-nitroarginine (L-NArg). The nitro group in L-NArg introduces additional chemical reactivity and functionalities to GO, namely enhancing the dispersibility in aqueous or biological environments, improving stability, and biocompatibility. We examine the impact of pH on the aforementioned structures, demonstrating the peculiarities of their pH-dependent behavior. Besides, Z-potential measurements were done for studying the stability problem of AA-functionalized GO complexes. Moreover, we characterize AA-functionalized GO nanocomposites using Impedance Spectroscopy. Our results reveal that L-NArg improves GO's stability more than L-Arg. On the other hand, the incorporation of AA onto GO sheets alters their electronic properties, namely enhancing electrical conductivity and charge transport characteristics. For comprehensiveness of our research, we additionally carried out the crystallographic structure, chemical compound, bond phase, optical properties, morphology, and particle size distribution analysis of AA-functionalized GO by XRD, FTIR-ATR, Raman, UV-Vis, SEM, and DLS techniques.

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Multifunctional Hydrogel Nanocomposite for on-demand Drug Delivery in Soft Tissue Cancer Treatment

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abstract, conference, advanced materials, bio-related application

This research project focuses on the development of a multifunctional hydrogel nanocomposite for local drug delivery in the treatment of soft tissue cancer. The nanocomposite incorporates superparamagnetic iron oxide nanoparticles (SPIONs) within a thermoresponsive hydrogel matrix. The aim is to address critical limitations in current approaches to soft tissue cancer treatment by providing a functional platform that mimics the extracellular matrix (ECM) and allows precise control over drug release.

Comprehensive physicochemical analysis, including scanning electron microscopy (SEM), Fourier-transform infrared spectroscopy (FTIR), and thermogravimetric analysis (TGA), is conducted to characterize the properties of the nanocomposite and optimize its performance. An alternating magnetic field (AMF) is utilized to facilitate on-demand drug delivery, while also enabling investigation into the thermal effects on tissue regeneration mechanisms.

The proposed system offers promising potential for improved soft tissue cancer regeneration, with tailored mechanical properties and enhanced drug delivery capabilities. This interdisciplinary research bridges materials engineering with clinical practice, aiming to advance therapeutic solutions for soft tissue cancer treatment. The novelty of this work lies in the integration of thermoresponsive hydrogels with nanostructural heat generators, presenting a novel approach to soft tissue cancer regeneration. This study contributes valuable insights to the field of biomaterials science and holds implications for the development of future therapeutic strategies.

Porous magnetic nanostructures for sensing SARS-CoV-2

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biosensor, nanostructure, implanted device

The intelligent engineering of nanostructures by means of appropriate surface or bulk functionalization will endow them with multi-functional capabilities, opening new opportunities in the biomedical field such as biosensing, drug delivery, imaging, medical implants, cancer treatment and tissue engineering. Here we demonstrate a cost-effective design approach for preparing nanostructures that show effective potential in rapid detection of SARS-CoV-2, based on the surface-enhanced Raman scattering (SERS) as well as power source for implanted medical devices. The three-dimensional (3D) porous nanoplatform with plasmonic-active nanostructures provides a high sensitivity for the detection of the virus by means of the remarkable SERS signal collection. The outstanding sensitivity of our SERS biosensor was demonstrated with SARS-CoV-2 at the detection limit of 1 fg mL^{-1} and 0.1 pg mL^{-1}, respectively. Our work demonstrates a low-cost design approach for targeted functional nanoplatform with potential for applications in biosensing and bioelectronics.

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Core-shell SPION-based nanostructures for biomedical and environmental applications

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Nanocomposites, SPIONs, nanomedicine, environment

Nanomaterials are being intensively explored in a wide range of fields, from biomedicine to environmental sciences, due to their high volume-to-surface ratio and easy surface modification. Among a variety of nanomaterials, superparamagnetic iron oxide nanoparticles (SPIONs) and their nanocomposites also offer unique magnetic properties, making them a promising medical tool for local delivery of various drugs, such as anticancer, anti-inflammatory, etc., as well as acting as an imaging agent or as a nanoscale platform for tissue regeneration. At the same time, these materials offer the possibility of adsorption on the surface of many different molecules, making them versatile for use in water purification as well. Depending on the experimental conditions during synthesis, features such as size, shape and magnetic properties can be modulated and tailored for a specific application.

Here, we will discuss the importance of experimental conditions in the synthesis and surface modification of SPION and SPION-based materials, as well as their implications for potential applications in both biomedicine and environmental studies. The correlation between various synthesis conditions and the physicochemical properties of magnetic nanomaterials will be presented focusing on the interdisciplinary approach.

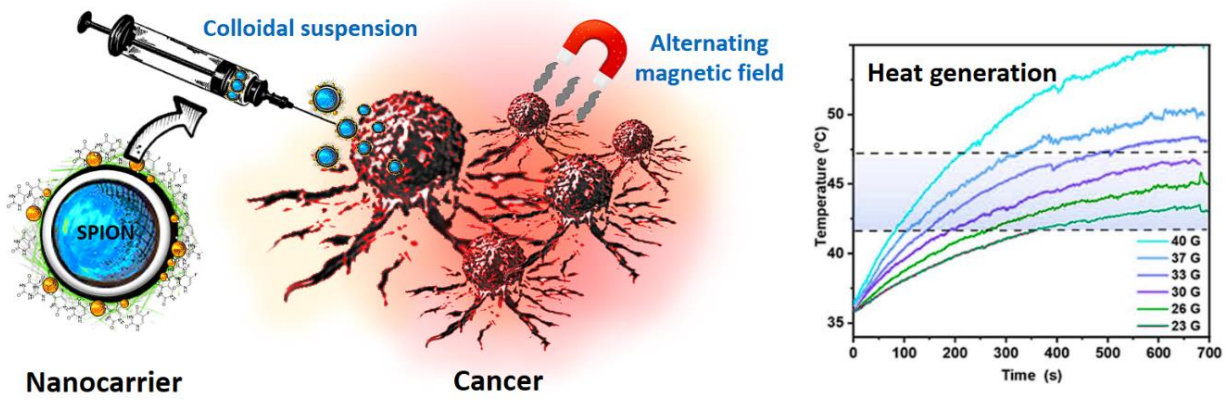

Figure 1. Schematic image of SPION-based suspension towards anticancer treatment and heat generation in alternating magnetic field

Superparamagnetic nanoparticles for the local drug release and magnetic hyperthermia

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SPIONs, Nanocomposite, Drug delivery, Anticancer treatment

Over the past 20 years, there has been a dramatic increase in the incidence of various cancers. The increased detection of various malignancies and their effective treatment requires the search for new approaches in anti-cancer therapy. One option is the use of nanomaterials and nanocomposites based on them to form a platform for simultaneous imaging, such as by nuclear magnetic resonance, and treatment by local drug release and temperature elevation directly in tumor tissues [1].

Here, we present results on the colloidal suspension based on superparamagnetic iron-oxide-based nanoparticles and hydroxyapatites as the matrix for the local anticancer drug release. The studies were focused on the optimization of the synthesis experimental composition, characterization of obtained material, and stability in aqueous solutions like PBS to be used in magnetic hyperthermia to generate heat locally and enhance the drug delivery. Core-shell particles were synthesized using a two-step wet co-precipitation method and stabilized with biocompatible organic molecules to produce stable colloidal suspension [2,3]. The heat generation effectiveness was determined using magnetic hyperthermia (MH), where the conditions to reach therapeutic temperature of the suspension in the constant and pulsed amplitude of alternating magnetic field (AMF) were optimized.

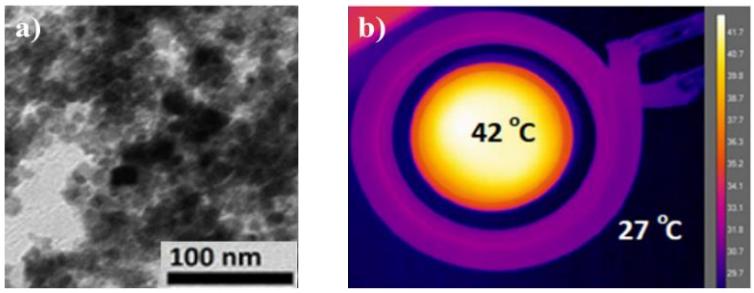

Figure 1. a) TEM image of prepared core-shell nanocomposite,
b) image from thermovision camera of suspension in AMF

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Effect of doping on the morphology, antibacterial and antifungal properties of silver-doped hydroxyapatite and silver-doped silicate-substituted hydroxyapatite nanoparticles

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hydroxyapatite, silver, silicate group, antibacterial application, antifungal application

Pure hydroxyapatite (HAp), hydroxyapatite doped with 1 mol% silver ions (HAp:1% Ag^+), and silicate-substituted hydroxyapatite doped with 1 mol% silver ions (Si-HAp:1% Ag^+) were synthesized by microwave-assisted hydrothermal technique and sintered at 450 °C. X-ray powder diffraction (XRD), Fourier-transformed infrared spectroscopy (FT-IR), Energy dispersive spectroscopy (EDS) and Transmission electron microscopy (TEM) were used for the study of structure, composition, and morphology of obtained materials.

We demonstrated the antibacterial and antifungal activity of hydroxyapatite doped with 1 mol% Ag^+ ion and silicate-hydroxyapatite doped with 1 mol% Ag^+ ion when compared to the pure HAp. Antibacterial activity was analyzed against the following bacteria: Staphylococcus aureus ATCC 6538, Staphylococcus epidermidis ATCC 12228, Enterococcus faecalis ATCC 51299, Klebsiella pneumoniae subsp. pneumoniae ATCC 700603, Pseudomonas aeruginosa ATCC 27853. These studies confirmed enhanced antibacterial activity for doped hydroxyapatite against both Gram-positive and Gram-negative bacterial strains. Antifungal activity of silver-doped nanohydroxyapatite (including silicate-substituted) has also increased for the reference strains C. albicans, C. kruzei and C. tropicalis.

Funding

The authors would like to acknowledge the National Science Centre Poland (NCN) for financial support within the Project 'Biocompatible materials with theranostics' properties for precision medical application' (No. UMO-2021/43/B/ST5/02960).

Development of biocompatible elastin-rich bioprosthetic material to overcome valve calcification

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calcification; bioprosthetic heart valve; GA cytotoxicity; vascular smooth muscle cells

Every year, over 250 000 heart valve transplant are performed worldwide. This is mainly due to calcification of the heart valves, which is present in 20-30% of patients over 65 years and in 48% over 85 years. There are two types of aortic heart valve implants: mechanical implants, made of synthetic materials, and implants made of biological materials. Mechanical implants have long durability but increase risk of a blood clot and therefore require lifelong anticoagulant therapy. Biological implants, on the other hand, are less resistant and require chemical preservation, which exposes the patient to the risk of aortic valve reintervention due to their limited durability. Glutaraldehyde (GA) is widely utilized as a crosslinking reagent for biological material to enhance biocompatibility, however it may also contribute to cytotoxicity. Moreover, GA has limited interaction with certain tissue components, such as elastin, resulting in incomplete distribution of GA, rendering the tissue more vulnerable to enzymatic degradation and diminishing its ability to retard calcification. Therefore, exploring new pre-treatment strategies for elastin-rich tissues (as an alternative to GA treatment).

The objective of this study is to develop anti-calcification pre-treatment using Fetuin A for elastin-rich xenogeneic materials such as bovine jugular vein. Fetuin A is a naturally occurring serum protein known for its anti-calcification properties. In vitro model of vascular calcification has been developed using human vascular smooth muscle cells (VSMCs) which were cultured for 14 days in medium containing 2mM of phosphates (Pi). At 3rd, 9th, 11th and 14th day of experiment cells were stained with 2% solution of Alizarin Red to visualize calcium deposition. Quantification of calcium deposition was performed using cetylpyridinium chloride. Anti-calcification action of Fetuin A was confirmed by the 20% reduction of calcium deposition compared to non-treated control, both in 11th and 14th day of cell culture in calcification medium. The GA-fixed bioprosthetic material reveiled substantial cytotoxicity which was demonstrated by the 40% reduction in metabolic activity (MTT assay) of VSMCs cultured in the presence of biomaterial extracts for 24 hours. Additional coating of biomaterial with amino acids such as glycine, glutathione or lysine combined with sodium borohydride abolished initial GA-related cytotoxicity as confirmed by an increase of metabolic activity and proliferation of VSMCs to the level of positive control. The same pattern in biocompatibility testing was observed when biomaterial samples were coated with amino acids and Fetuin A.

Funding

This project (grant no. 2021/03/Y/ST5/00219) is founded by the “M-ERA.NET 3 Call 2021”.Anti-calcification treatment of elastin-rich bioprosthetic materials using Fetuin A for aortic valved conduits (VENUS). Task manager at Hirszfeld Institute of Immunology and Experimental Therapy: Honorata Kraśkiewicz, PhD.

Fluoride release profile for commercial fissure sealant (Flow-Color (red), Arkona) in various pH

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Fissure sealant, fluoride, fluoride release, pediatric dentistry

This following study is dedicated to analyzing the fluoride release profile for commercial and readily available dental fissure sealant – Flow-Color manufactured by Arkona (Poland) in red coloring and followed by structural analysis by means of FT-IR infrared spectroscopy. Samples were obtained as 5 x 2 mm discs by polymerization in teflon mold. As irradiation source, a LED lamp (500-800 mW/cm^2) was used, with irradiation time of 5s and 2 mm distance maintained.

ORION 9609 ion-selective electrode (Thermo Fisher Scientific Co., Waltham, MA, USA) connected to a pH/ion meter CPI-551 Elmetron microcomputer was utilized for fluorine release studies. Fluoride ions concentration were registered at intervals of 3, 24, 24, 48, 72, 96 and 168h in artificial saliva at 4 pH values (4.5; 5.5; 7; 7.5) as well as in deionized water for reference. Artificial saliva was used as an environment mimicking the oral cavity.

The highest released concentration was denoted after 168h interval in artificial saliva of pH = 7.5 (0.1075 ppm). The greater the fluoride release, the greater are the clinical benefits of the utilized sealants. Cummulative plots showed that in artivicial saliva (pH = 4.5) and in deionized water the summarized concentrations of released fluoride were the lowest while in pH = 5.5; 7.0 and 7.5 stayed on the comparative level. In the analyzed period of time (3-168h) sealant maintained high potential of fluoride release.

Funding

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Hierarchical Au-CdS electrodes based on self-assembly polystyrene spheres crystals as nanocatalytic sensors for biomedical applications

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self-assembly crystals, periodic structures, nanosphere lithography, nanocatalysis, gold-semiconductor electrodes, biomedical sensing

Biosensors play a critical role in improving our lives. Due to their ability to precisely detect a huge variety of chemicals and biomolecules they find applications in healthcare and environmental monitoring, among others. We present a gold-semiconductor electrode based on periodic self-assemble crystals of polystyrene spheres [1] with electrochemically deposited semiconductor nanoparticles for efficient photo-nanocatalytic biomedical sensing [2]. The nanosphere lithography was performed with PS nanopheres crystal deposited on the water surface, which was subsequently etched with argon plasma. After gold sputtering and PS removal, cadmium and sulfur were deposited electrochemically and chemically, respectively. The improved photo-nanocatalytic activity, which determines the efficiency of the designed metal-semiconductor electrode in electrochemical sensing, was presented. The impact of the morphology and stoichiometry of semiconductor layers on the electrode properties was evaluated.

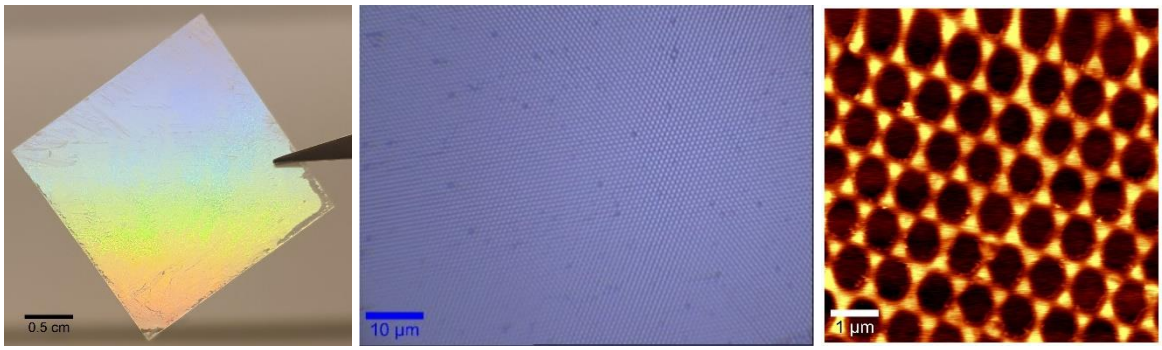

Figure 1. Gallery on the images on preparation of the nanostructures made using nanospehere lithography, a) electrode modified with gold, b) substrate with 2D monolayer of latex particles, and c) periodical Au structures after etching.

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The impact of Er:YAG laser on titanium alloy surface considering exposure parameters in dental treatment

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Titanium alloy, Ti6Al4V and Ti6Al7Nb, Er:YAG laser, Peri-implantitis

Peri-implantitis, inflammation around implants, can cause pocket formation and bone loss [1]. The Er:YAG (Er^{3+}: $Y_3Al_5O_{12}$) laser is promising for biofilm removal, but safety concerns persist. Ti6Al4V and Ti6Al7Nb alloys, common in implants, offer strength and biocompatibility, with Ti6Al7Nb preferred due to lower toxicity [2]. This study explores safe Er:YAG laser use on titanium implants to maintain oral hygiene, aiming to remove deposits without damaging the surface. Scanning Electron Microscopy (SEM) analysis assessed surface alteration of studied implants in the context of preventing impaired osseointegration after decontamination process.

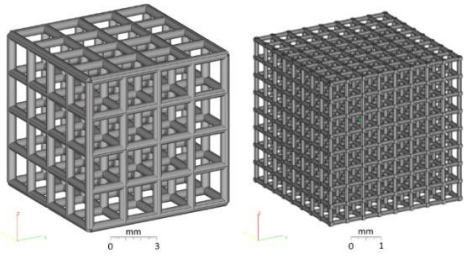

Figure. Models of a) Ti6Al4V and b) Ti6Al7Nb scaffolds.

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Influence of the type of thermoplastic recycled material on the rheological and mechanical properties of the plastic-based composites towards circular economy

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composite, regranulate, IML/IMP-in mould labeling/painting

Technological progress is inevitably linked to the production of new machines, new materials and advanced technologies, as well as generation of post-industrial waste. Therefore, there is a need to reuse post-industrial waste including post-product thermoplastic materials towards reduction of environmental pollution with plastic-based waste.

In our research, we focused on producing an effective coating on the metal surface to reduce the number of waste materials that are challenging to be reused that has a potential to be applied in a wide range of fields - from the furniture industry to the automotive and biological industry. We obtained a new material combining thermoplastic regranulate from post-industry waste with organic film and/or PUR lacquer (PA6/PP-organic coat-lacquer/lacquer composite) using IML and IMP technologies, achieving highly effective adhesion between the composite and the film/lacquer to maintain highly effective and uniform coverage of the substrate protecting the surface from the external conditions.

Using IML technology, we eliminated operations associated with the traditional process, such as surface preparation after injection molding, painting of parts in the booth, and elimination of film application through hot-stamping, while using IMP technology, we reduced the cycle time from 20 minutes to 3 minutes compared to SMC technology - molding the material in a plate mold. In both technologies, we used regranulate thermoplastics and eliminated material waste, which has a negative impact on the environment.

These technologies improve mechanical properties such as tensile strength, Charpy impact strength, lower part weight using organic sheet compared to steel parts, improved scratch resistance, reduced part failure rates by 20%, eliminated additional operations affecting part contamination after the injection process, and protected the environment from solvents in the painting process.

In IML and IMP technology, we achieved adhesion between the composite and the film/paint, where we did not observe any peeling of the film on the coated surface it possible to use the proposed material in many sectors.

Role of Synthesis Parameters in Optoelectronic and Antibacterial Properties of Microcrystalline β-Ga_2O_3 and GaO(OH)

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gallium oxide, gallium oxyhydroxide, surface properties, antibacterial

β-Ga_2O_3, a wide band gap semiconductor, has been attracting interest recently due to its applications in high-power/high frequency telecommunications, next generation solar cells, sensors, etc. Nano- and microcrystalline β-Ga_2O_3 is gaining significance for its potential uses, including antimicrobial. However, the fundamental nature of the antibacterial action by Ga_2O_3 remains not well established. In particular, the role of surface phenomena in this regard is not understood. Moreover, while Ga_2O_3 is known for its antibacterial efficacy, there is almost no research reported on the antibacterial properties of GaO(OH), the synthesis precursor of Ga_2O_3. Thus, there is a need for a simple synthesis protocol and a thorough characterization of these materials. We synthesized β-Ga_2O_3 microcrystals with controlled morphologies via a hydrothermal method. Deionized water, ammonium hydroxide, and gallium nitrate salt were mixed with pH levels ranging from 5 to 10 to create the samples. The GaO(OH) samples were then produced by annealing, followed by a high-temperature calcination, leading to β-Ga_2O_3, the final product. Analysis of the optoelectronic properties (electronic structure and charge dynamics) of the obtained materials was performed using photoluminescence spectroscopy as well as time- and energy-dependent surface photovoltage before and after a remote plasma treatment (RPT). The samples were also characterized by electron microscopy, Fourier-transform infrared (FTIR) and X-ray diffraction spectroscopies. The biological assays of our samples in a DMSO broth were cultured with *Staphylococcus aureus* and *Escherichia coli* and then light absorption was used to determine the minimum inhibition concentrations. One of our goals was to addresses the impact of the precursors' pH on the properties of β-Ga_2O_3 and GaO(OH). Systematic analysis revealed that the pH controllably affected the morphology of the particles and strongly impacted the crystal lattice defects. Our results agree with theoretical calculations for sub-bandgap states and explicate the related surface charge dynamics. We also demonstrate a successful modification of the surface properties following RPT. The correlation between the surface chemistry and pH was confirmed by FTIR experiments. Antibacterial assays established an increased inhibition of the *E. coli* bacteria growth at higher precursor pH, while no conclusive correlation was observed in similar assays of *S. aureus* possibly due to its Gram-positive surface.

Evaluation of the microbial, cytotoxic, and physico-chemical properties of the zirconia crowns used in pediatric dentistry

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zirconia crowns, material composition, biofilm

Prefabricated zirconia crowns are the response to the increasing esthetic demands put on modern pediatric dentistry. They are prefabricated crowns allowing full coronal coverage of both anterior and posterior deciduous teeth. Their convenience is particularly noticeable in the anterior section of the dental arch. Zirconia advantages are good aesthetics, high strength, biocompatibility, high wear, and corrosion resistance [1]. They can be used in patients with Ni- Cr allergy or sensitivity. The disadvantage is high cost [2].

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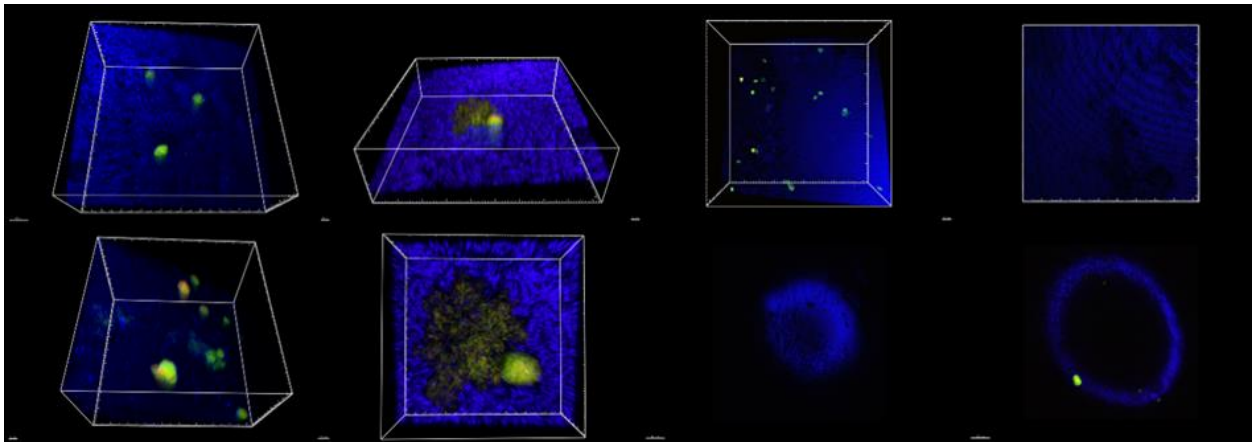

Figure 1. Confocal microscopy imaging of zirconia crown material after exposure to biofilm

The aim of the study is to analyze the composition, properties of the biomaterial of zirconia crown, its potential cytotoxic properties and ability to form a bacterial bio-film, which is crucial for maintaining oral health. The structure of zirconia crown was investigated based on X-Ray Powder Diffraction (XRPD) patterns. For microbiological assay a quantitative assessment of the adhesion ability of the strains analyzed and the formation of a mixed biofilm on

the dental material used was conducted, followed by confocal microscopy. Lastly histology assay was performed using direct contact on the Balb/3T3 normal mouse fibroblast line. The material of zirconia crowns is characterized by a moderate impact on the surrounding tissues. Like stainless steel crowns used in pediatric dentistry, they al-low full coverage and show the lowest risk of clinical failure. The material itself demonstrates a low degree of biofilm adhesion.

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Luminescence of Ce^{3+}-doped $Ca_{10}(PO_4)_6Cl_2$ phosphors

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Spectroscopy, Chlorapatite, Cerium(III) ions, Biomaterial, Nanosized materials

Intensive research are currently underway to unearth novel luminescent materials possessing desirable characteristics tailored for medical applications, particularly as theranostic agents for therapeutic interventions and bioimaging [1, 2]. In this aim, a pioneering approach involved the fabrication of single-phase calcium chlorapatite ($Ca_{10}(PO_4)_6Cl_2$, abbreviated as CaClAp) phosphors, activated with varied concentrations of Ce^{3+} ions. These phosphors were successfully synthesized via hydrothermal method with the goal of investigating how varying dopant concentration affect the physicochemical attributes of the materials. The investigation encompassed an exploration of the structural modifications, photoluminescence (PL) behavior, energy transfer phenomena, substitution site preferences, and fluorescence lifetime.

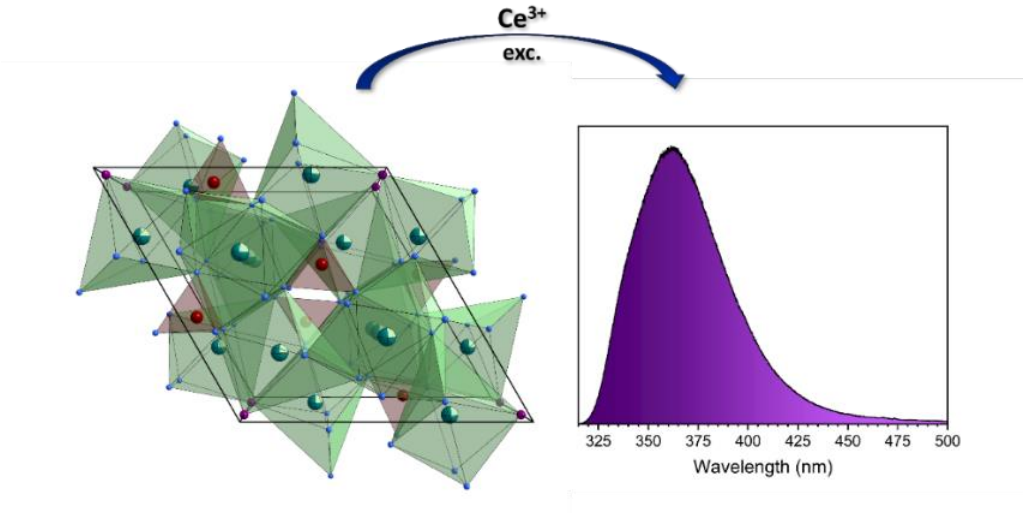

Figure 1. The unit cell and emission spectrum of the Ce^{3+}-doped $Ca_{10}(PO_4)_6Cl_2$

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Optimizing Synthesis Parameters for Near-Infrared Emitting Ag_2S Quantum Dots

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quantum dots, silver sulfide, fluorescence, nanoparticles, theranostics

Enhancing the synthesis of quantum dots holds paramount significance as it allows for precise modulation of their spectroscopic attributes through meticulous adjustment of reaction parameters such as temperature, duration, pH, capping agent, and reagent concentration. Among these, silver sulfide quantum dots (Ag_2S QDs) stand out for their immense potential in theranostics owing to a combination of favorable traits: minimal toxicity, heightened quantum yield, robust photostability, biocompatibility, and emission falling within the near-infrared (NIR) spectrum, facilitating advanced imaging capabilities. While traditional organic fluorescent dyes boast commendable optical characteristics, they grapple with a multitude of challenges, notably the vexing issue of autofluorescence stemming from inherent fluorophores within biological systems. Enterprising advancements in silver sulfide quantum dots, particularly those emitting in the NIR II window (1000-1400 nm), present a promising avenue for addressing these hurdles. Their emission properties, extending into the second NIR window, afford unparalleled advantages, including reduced light scattering and negligible autofluorescence, thereby enabling deep-penetration imaging with unprecedented clarity and precision. Within study, we unveil a refined synthesis methodology for Ag_2S QDs, fortified with an innovative stabilizing shell. Moreover, our endeavors delve into the comprehensive characterization of these QDs, elucidating their emission and excitation spectra, alongside delving into the intricacies of their lifetime dynamics.

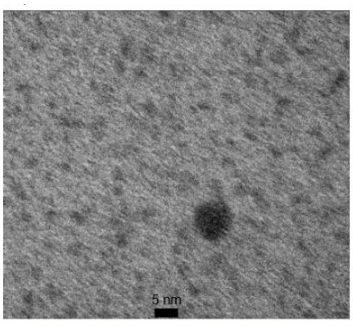

Figure 1. TEM image of Ag_2S QDs

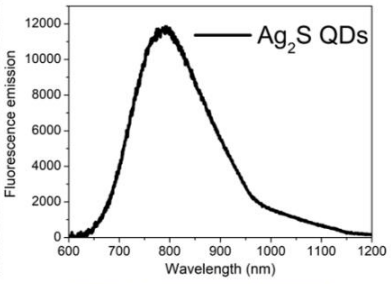

Figure 2. Fluorescence emission spectrum of Ag_2S QDs

References

[1] M. Gordel-Wójcik, et al., Journal of Physical Chemistry Letters, vol. 14, no. 49, pp. 11117–11124, 2023

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Structural and spectroscopic properties of $Ca_{1-x}Sr_xF_2$: Nd^{3+} nanocrystals

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fluorite, nanomaterials, Nd^{3+}, bio-imaging, optical spectroscopy

Laser hosts based on **CaF_2**, and **SrF_2** doped with rare earth ions are well known and broadly described in the literature. Similarly, nanomaterials of these fluorides are commonly used as nanothermometers, up-converting nanoparticles or for bio-imaging. However, their mixed systems are hardly described in the literature. There are only few papers about **$Ca_xSr_{1-x}F_2$:Nd^{3+}** compounds and all are about crystals and ceramics for lasers.

It is well-known in the literature that nanoceramics based on **XF_2** nanosized powders have great potential as scintillators. There is a lot of literature concerning nanosized powders and ceramics, however there is no works concerning **$X_{1-x}Z_xF_2$** mixed systems and nanoceramics based on these systems, which explore its scintillation properties.

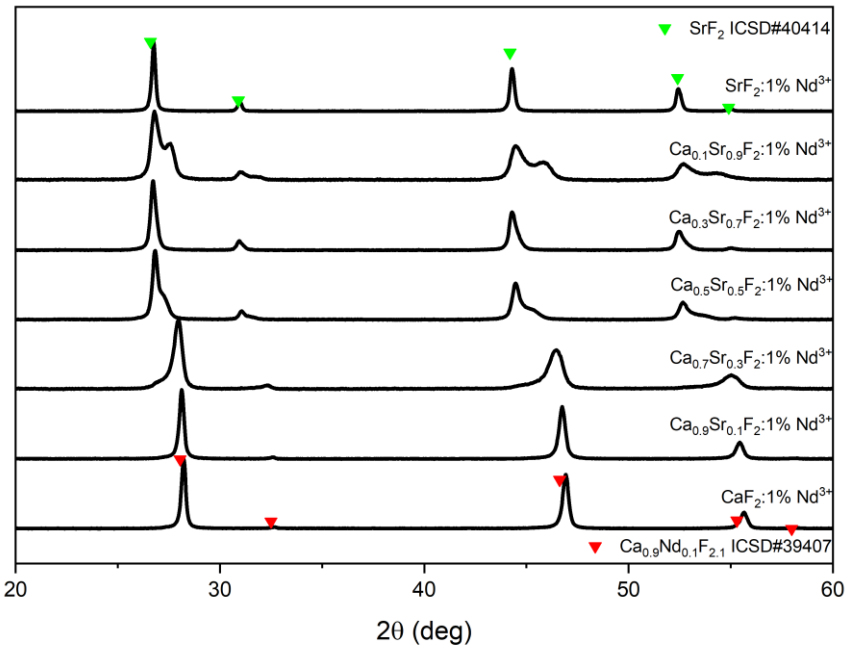

Figure 1. Powder diffractograms of $Ca_{1-x}Sr_xF_2$: 1 mol% Nd^{3+} heat-treated at 600 °C for 3 hours

To date, the first attempt at optimisation of the co-precipitation synthesis process has been performed. It led us to proposing the following synthesis route for the synthesis of $Ca_{1-x}Sr_xF_2$ doped with Nd^{3+} ions.

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